# EVALUATION OF SPRING-WATER CHEMISTRY DATA

Forty-four percent of Kentuckians rely on groundwater as a source of drinking water, either from public or private systems. In addition, many Kentuckians use groundwater for industrial, agricultural and commercial purposes. Groundwater provides the baseflow to Kentucky streams. In fact, groundwater constitutes greater than 90% of Kentucky's freshwater resources. Consequently, groundwater is an important resource and needs to be managed and protected. The collection of physical and chemical data from the regional springs sampled during this study helps to address the need for base-line information. These data are especially important in Kentucky's karst regions where surface and groundwater function as conjunctive systems.

Some of the parameters assessed in this study have limits established by the EPA for treated drinking water supplied to the public. The EPA (2000) defines the following three types of drinking water standards: Maximum Contaminant Levels, Secondary Drinking Water Regulations and Health Advisories:

Maximum Contaminant Level (MCL) is defined as "the highest level of a contaminant that is allowed in drinking water." MCLs are legally enforceable limits applied to "finished" public drinking water based on various risk levels, ability to treat and other cost considerations. MCL standards are health-based and are derived from calculations based on adult lifetime exposure, with drinking water as the only pathway of concern. These standards are also modified by other considerations, including the effectiveness and cost of treatment.

Secondary Drinking Water Regulations are defined as "non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor or color) of drinking water." In common usage, this is often referred to as Secondary Maximum Contaminant Level (SMCL).

Health Advisory is defined as "an estimate of acceptable drinking water levels for a chemical substance based on health effects information; a Health Advisory is not a legally enforceable Federal standard, but serves as technical guidance to assist Federal, state and local officials." Again, reflecting common usage, this term has been modified slightly and is referred to in this document as the Health Advisory Level (HAL).

Most of the information provided about various chemical parameters is cited from EPA (1998, 1999, 2000) and World Health Organization (1996) publications.

### *Boxplots*

Boxplots are used to graphically depict the sample results of all 12 springs on one diagram so that comparisons can be made. Data from four springs in the NE study area are illustrated in the top third of the graph, and data from eight springs in the SW study area are shown in the lower two-thirds of the graph. The springs are arranged from largest to smallest volume in each group.

Boxplots were used to assess skewed datasets, such as water quality data containing numerous non-detect values. Skewed datasets are more appropriately described by the 5-Number Summary and Interquartile Range (IQR) than the mean and standard deviation. The 5-Number Summary consists of quartiles: $Q_0$ (minimum value), $Q_1$ (first quartile, or median of the lower half of the dataset), $Q_2$ (median), $Q_3$ (third quartile, or median of the upper half of the dataset) and $Q_4$ (maximum value). The Interquartile Range is calculated as the difference between $Q_3$ and $Q_1$ and represents 50% of the data values in a set.

Boxplots graphically depict the central tendency (location about which data values cluster) and scatter of values in a dataset utilizing the 5-Number Summary. The "box" in a boxplot extends from $Q_1$ to $Q_3$, representing the Interquartile Range. The median is represented by a vertical line inside this box. Horizontal lines ("whiskers") are extended from $Q_1$ down to the lowest value within 1.5 IQR of $Q_1$ and from $Q_3$ up to the highest value within 1.5 IQR of $Q_3$; a small vertical bar ("fence") on the end of each line indicates the location of these two values. Outliers, values more than 1.5 IQR from the quartiles, are denoted by an open square. Extreme outliers, values more than 3.0 IQR from the quartiles, are denoted by a red cross within a square.

Outliers are significant because they represent distinct deviations from the bulk of the data values in a set. In water quality data, values are generally skewed to the right, or positively skewed, due to the presence of a few high outliers. Most of the values in this type of data set cluster at or near 0, or some laboratory-defined detection limit (represented on a boxplot by a left-truncated appearance).

### *Nutrients*

Nutrients are widespread nonpoint source contaminants in karst groundwater, which are commonly related to agricultural practices. Nutrient sources include fertilizers and manure applied to the land surface for crop production, feedlots, pastures, dairy, poultry and swine operations (Berryhill, 1989). Nutrients are particularly important in surface water, where eutrophication may be caused by excessive nutrient enrichment of water. This enrichment can cause an overabundance of some plant life, such as algal blooms and may also have adverse effects on animal life, because excessive oxygen consumption by plants leaves little available for animal use. Nutrients included in this report are nitrate-nitrogen, nitrite-nitrogen, ammonia, orthophosphate and total phosphorous.

## Nitrate

Nitrate ($NO_3$-N) occurs in the environment from a variety of anthropogenic and natural sources: nitrogen-fixing plants such as alfalfa and other legumes, nitrogen fertilizers, decomposing organic debris, atmospheric deposition from combustion and human and animal waste. Nitrate is reported either as the complex ion $NO_3$, or as the equivalent molecular weight of nitrogen-N. Since 1 mg/L of nitrogen equals 4.5 mg/L nitrate, the drinking water MCL of 10 mg/L nitrate-N equals 45 mg/L nitrogen. In this report, results are reported as "nitrate-N." In infants, excess nitrate consumption can cause methemoglobinemia or "blue-baby" syndrome (Lambert, 1976; EPA, 1999). In adults, possible adverse health effects of nitrate ingestion are under study and much debated. Because nitrate is difficult to remove through ordinary water treatment, its occurrence at levels above the MCL in drinking water sources is a problem. High nitrate levels also encourage the growth of algae and other organisms in streams. The unnatural accelerated growth of these organisms depletes the available oxygen in water and creates an oxygen deficient environment uninhabitable by many other organisms. Thus, streams high in nitrate content will have a smaller diversity and population of organisms.

Table 4 shows nitrate-N values in mg/L from the 12 sampled springs over eight quarters. None of the values are above MCL. However, compared to a typical reference value of less than 2 mg/L for a relatively pristine karst spring, nitrate-N levels are moderately high in most intensively farmed karst basins, especially the SW study area. Figure 39 shows the overall median value of nitrate in the SW study area to be about 2.4 times higher than the NE study area.

| **Flow Condition** | Moderate | Moderate | Low | Low | Moderate | Low | Low | Moderate | - |
|---|---|---|---|---|---|---|---|---|---|
| **Sample Date** (SW) | **1/19/99 & 1/20/99** | **5/17/99 & 5/18/99** | **8/24/99 & 8/25/99** | **12/08/99 & 12/09/99** | **4/26/00 & 4/27/00** | **8/22/00 & 8/23/00** | **1/09/01 & 1/10/01** | **5/15/01 & 5/16/01** | |
| ***Spring*** (SW) | | | | | | | | | MEDIAN |
| *River Bend* | 6.24 | 5.6 | 5.74 | 5.24 | 5.38 | 5.63 | 6.28 | 6.85 | 5.69 |
| *Barkers Mill* | 5.45 | 5.79 | 5.04 | 4.54 | 6.19 | 5.18 | 5.02 | 5.45 | 5.32 |
| *Wright* | 6.85 | 4.75 | 3.66 | 3.1 | 5.81 | 4.18 | 7.05 | 4.9 | 4.83 |
| *Mill Stream* | 4.84 | 6.08 | 4.02 | 3.46 | 3.64 | 3.84 | 6.73 | 6.28 | 4.43 |
| *King* | 4.72 | 3.5 | 3.8 | 3.46 | 4.72 | 3.82 | 4.23 | 4.81 | 4.03 |
| *Cook* | 3.62 | 4 | 3.86 | 3.32 | 4.59 | 4 | 5.49 | 4.93 | 4 |
| *Walton* | 3.93 | 3.23 | 3.66 | 3.39 | 6.24 | 3.8 | 4.61 | 4.61 | 3.87 |
| *Brelsford* | 2.64 | 1.74 | 1.38 | 1.15 | 2.35 | 1.38 | 2.49 | 1.9 | 1.82 |
| **Sample Date** (NE) | **1/27/1999** | **5/11/1999** | **8/25/1999** | **12/1/1999** | **4/26/2000** | **8/23/2000** | **1/10/2001** | **5/15/2001** | |
| ***Spring*** (NE) | | | | | | | | | |
| *French Creek* | 2.58 | 2.62 | 2.76 | 2.49 | 2.98 | 2.51 | 3.59 | 2.96 | 2.69 |
| *Boiling* | 2.42 | 1.31 | 1.92 | 1.2 | 2.1 | 2.06 | 3.03 | 2.53 | 2.08 |
| *Buttermilk Falls* | 1.94 | 1.79 | 1.7 | 1.72 | 1.83 | 1.83 | 2.21 | 2.06 | 1.83 |
| *Head of Wolf* | 0.88 | 0.88 | 0.72 | 0.68 | 0.81 | 0.68 | 1.04 | 0.59 | 0.77 |

**Table 4: Nitrate – N Concentration (mg/L) in Springs, 1999 - 2001**

Comparing land use of the two areas, the SW area has a combined agricultural land-use area of approximately 80% as opposed to 45% for the NE area; in fact, the area under row crop cultivation (a process that uses more fertilizer) is approximately equal to the total agricultural area of the NE (Figure 40). A higher nitrate concentration in runoff and groundwater from the SW area is to be expected (Boyer and Alloush, 2001). Also, the basin with the lowest median value in each area (Brelsford in SW, Head of Wolf in NE) is the basin with the greatest amount of *Forest* (either deciduous, mixed or woody wetlands), indicating that, although nitrate is present naturally, the elevated nitrate numbers in the other areas result primarily from agricultural land use. High and low median values of nitrate-N in each study area are listed below along with percentages of agricultural land use. These figures reinforce the contention that elevated nitrate-N is due to more intensive agriculture.

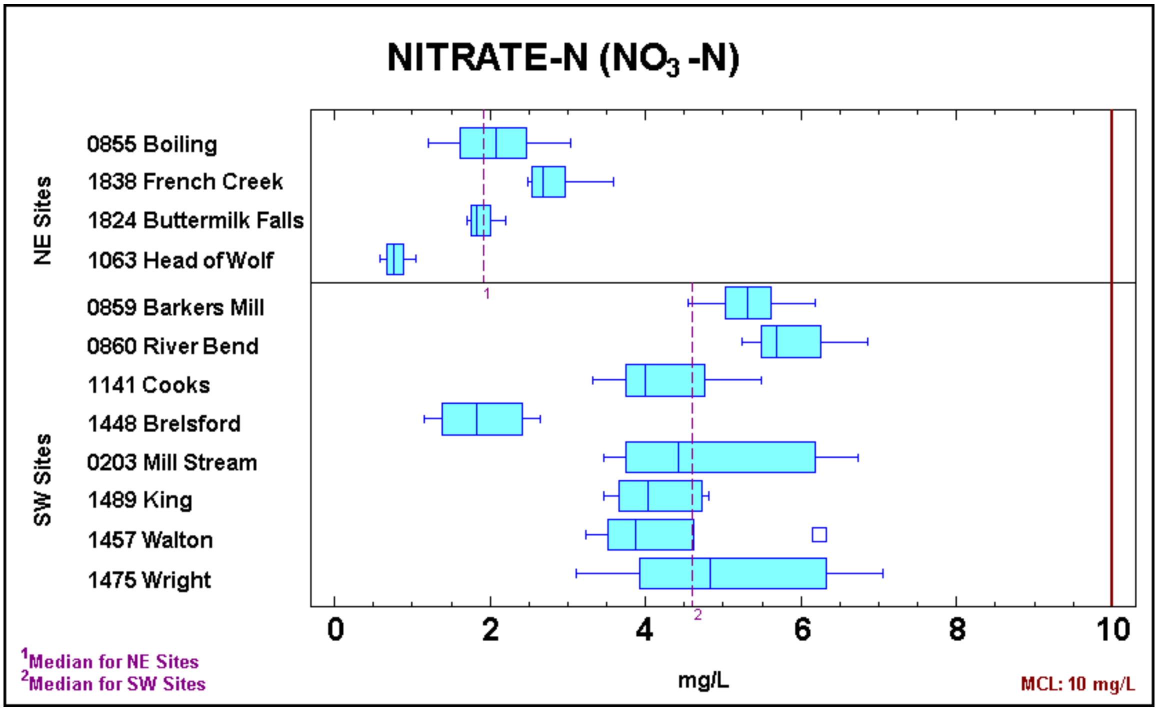


**Figure 39: Boxplots of Nitrate-N Concentration in Springs; MCL equals 10 mg/L**

**Median Nitrate-N in SW:**
**Low: 1.82** mg/L @ *Brelsford*
(Total Ag: 65.4% - 52.2% Pasture and Hay, 13.2% Row Crops)

**High: 5.69** mg/L @ *River Bend*
(Total Ag: 87.7% - 44.3% Pasture and Hay, 43.4% Row Crops)

**Median Nitrate-N in NE:**
**Low: 0.77** mg/L @ *Head of Wolf*
(Total Ag: 27.9% - 12.7% Pasture and Hay, 15.2% Row Crops)

**High: 2.69** mg/L @ *French Creek*
(Total Ag: 67.9% - 43.9% Pasture and Hay, 24.0% Row Crops)

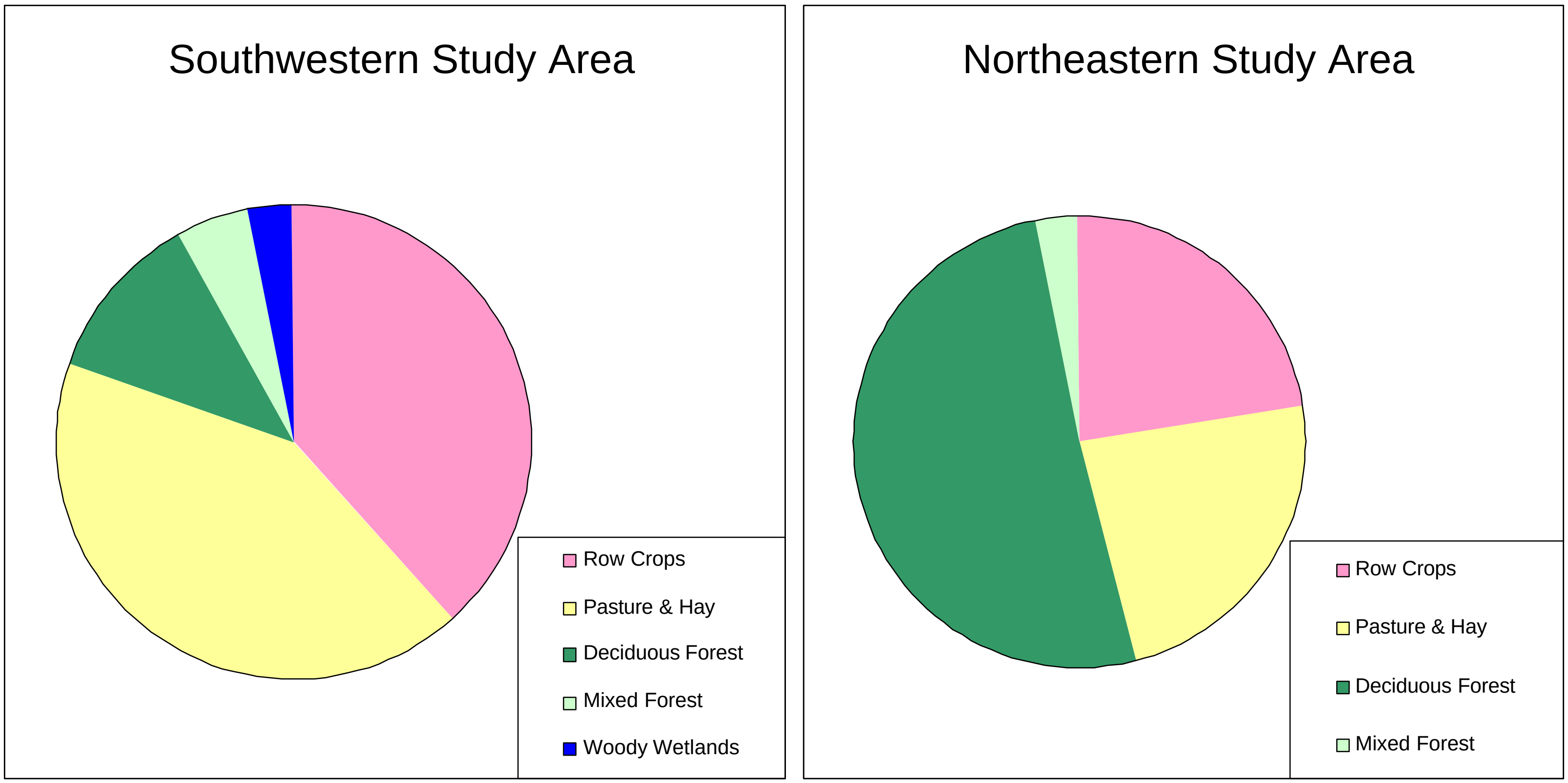


**Figure 40: Pie-Chart Comparison of Primary Land Cover Types within the two Study Areas**

## Nitrite

Nitrite ($NO_2$-N) also occurs naturally from many of the same sources as nitrate. Nitrite, however, is an unstable ion and is quickly converted to nitrate in the presence of free oxygen. Nitrite is reported either as the complex ion $NO_2$, or as the equivalent molecular nitrogen-N. The MCL for nitrite-N is 1 mg/L. Nitrite is not a significant nonpoint source pollutant, although it may contribute to high levels of nitrate. Within the study areas, only one spring basin (Wright) has consistent detections of nitrite and even those concentrations are low (Figure 41). The median values of both study areas are essentially identical which indicates that nitrite either is nearly nonexistent or that it does not persist in groundwater within these aquifers, but is rapidly converted to nitrate. The anomalous Wright Spring consists of nearly 90% agricultural land use and may have greater concentrations of nitrite simply because there is so much more available from runoff that conversion to nitrate cannot keep pace with the total amount coming into the water system.

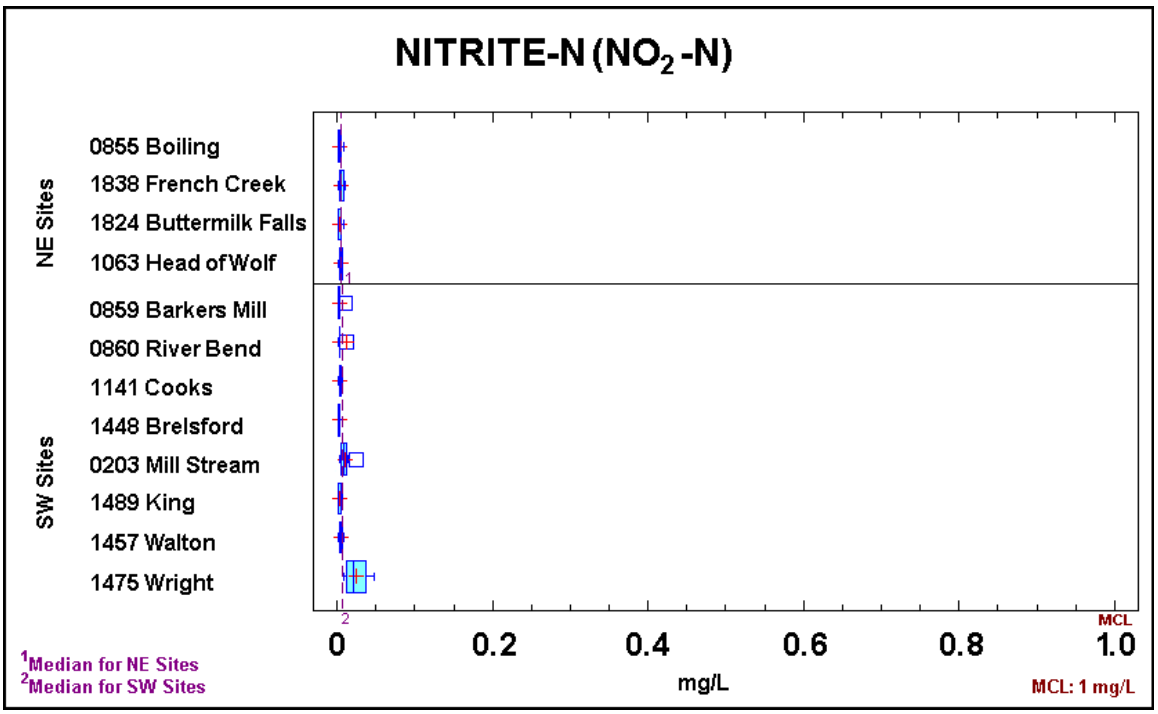


**Figure 41: Boxplots of Nitrite-N Concentration in Springs**

## Ammonia

Ammonia ($NH_3$) occurs naturally in the environment, primarily from the decay of plants and animal waste. The principal source of man-made ammonia in groundwater is from ammonia-based fertilizers. No drinking water standards exist for ammonia; however, the risk-based number calculated by the Kentucky Department for Environmental Protection for tap water is

0.110 mg/L.  Only three springs had any detections of ammonia during the course of the study (Figure 42), and only one (Mill Stream Spring) was near the DEP limit of 0.110 mg/L.

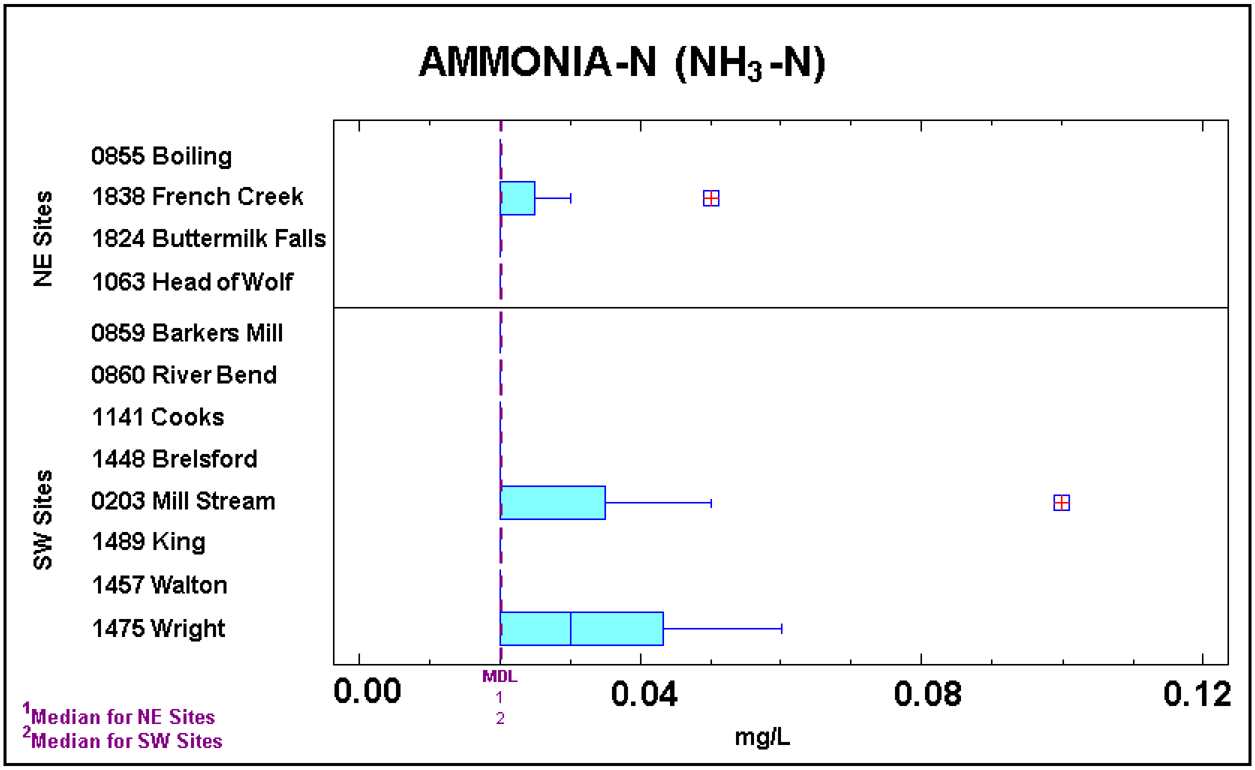


**Figure 42:  Boxplots of Ammonia Concentration in Springs**

## Phosphorus

Phosphorus (P) is a common constituent of rocks, especially the carbonate rocks of Kentucky. However, inorganic phosphorus has a low solubility and readily adsorbs onto soil particles, so availability in groundwater is limited.  Phosphorus is a constituent in phosphate fertilizers, sewage and animal waste.  Phosphorus contributes to the eutrophication of surface water by encouraging "algal blooms" and the subsequent reduction of dissolved oxygen.  This problem can especially affect lakes and sluggish streams, as well as conjunctive surface water/groundwater systems such as karst.  Two forms of phosphorus are discussed in this report: orthophosphate and total phosphorus.  Neither orthophosphate nor total phosphorus has a drinking water standard.  For the purposes of this report, total phosphorus data are compared to the surface water limit of 0.1 mg/L recommended by the USGS.

## Ortho-P

Orthophosphate-P ($PO_4$-P), or simply "orthophosphate" or "ortho-P," is the final product of the dissociation of phosphoric acid, $H_3PO_4$. It occurs naturally in the environment most often as the result of the oxidation of organic forms of phosphorus and is found in animal waste and detergents. In most pristine natural systems, orthophosphate occurs at very low levels (<0.01 mg/L). Orthophosphate is the most abundant form of phosphorus, usually accounting for about 90% of the total available phosphorus.

Local geology controls some natural variation of total phosphorous in waters. Phosphate and nitrogen are limiting nutrients. An increased availability of the limiting nutrient (organic enrichment) results in eutrophic conditions in lakes and streams. Generally, total phosphorous above 0.1 mg/L has been considered a threshold at which deleterious effects occur, though in some areas (e.g. the mountainous regions of eastern Kentucky, the Outer Bluegrass, the Pennyroyal) this threshold is probably significantly lower.

Figure 43 shows that orthophosphate concentrations are generally higher in the more intense agricultural areas. However, land use alone may not account for the higher orthophosphate concentrations in Boiling and French Creek springs. Farmers in those areas may prefer and preferentially use phosphate-based fertilizers; however, other factors unknown to the authors may also affect orthophosphate levels.

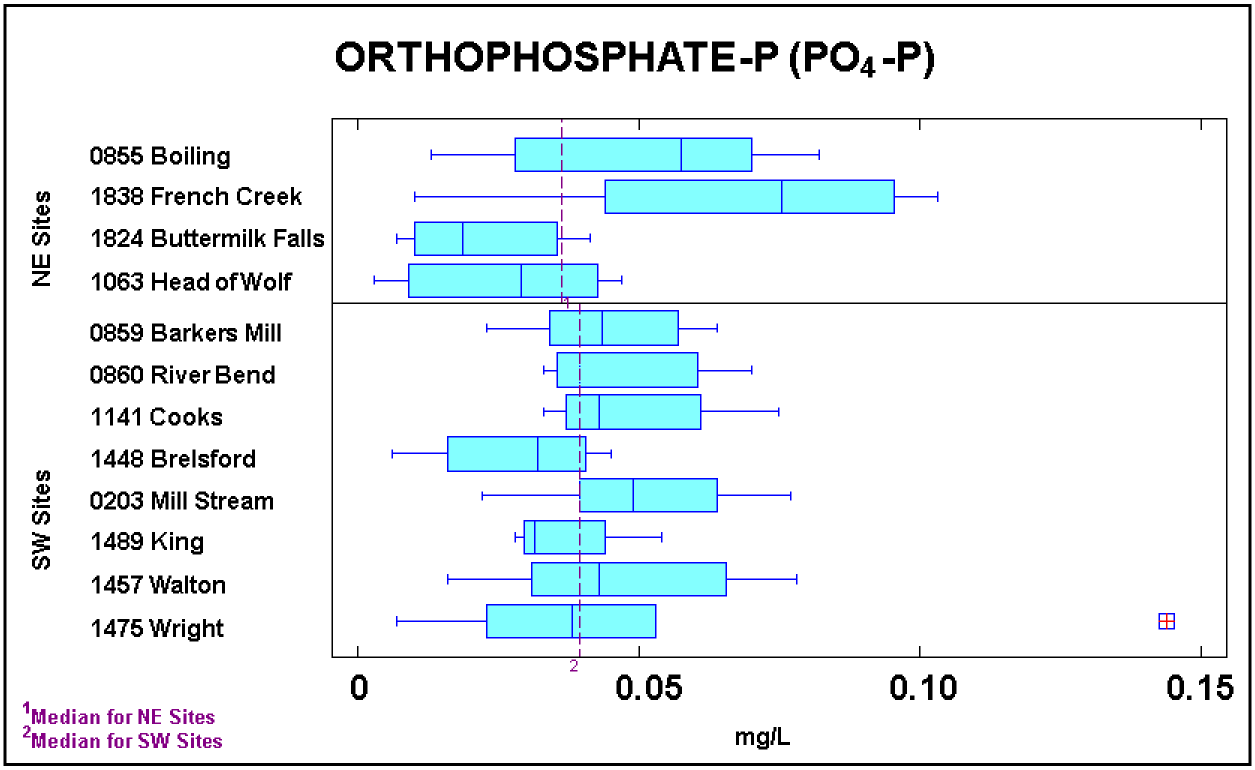


**Figure 43: Boxplots of Orthophosphate-P Concentration in Springs**

## Total Phosphorus

Total phosphorus (P or Total-P) is the sum of organic and inorganic forms of phosphorus. During the course of this investigation, the MDL for P changed several times. Some of the MDLs were above the standard being used while some were below. Given the changes in MDL, the results are impossible to interpret in any meaningful fashion. Therefore no boxplot is shown. Total-P was detected at all sites, and only exceeded the 0.1 mg/L standard three times. Nevertheless, these data suggest that phosphorus may be entering these groundwater systems in enough quantity to be of concern from a human health standpoint. Further investigations, with newer methods of detection, are recommended for both areas.

## Total Dissolved Solids

Total Dissolved Solids (TDS) measures the solids remaining in a water sample filtered through a 1.2 µm filter. According to the World Health Organization (WHO, 1996), the compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulfate, silica and nitrate-n. High TDS affects the taste and odor of water, and, in general, levels above 300 mg/L become noticeable to consumers. As TDS increases, the water becomes increasingly unacceptable. Although the SMCL for TDS is 500 mg/L, levels above 1200 mg/L are unacceptable to most consumers. Because TDS measurements may include a variety of parameters, which can be naturally occurring or anthropogenic, its value as an indicator of nonpoint source pollution is limited. Median values of TDS were found below the SMCL of 500 mg/L and no value exceeded the SMCL (Figure 44).

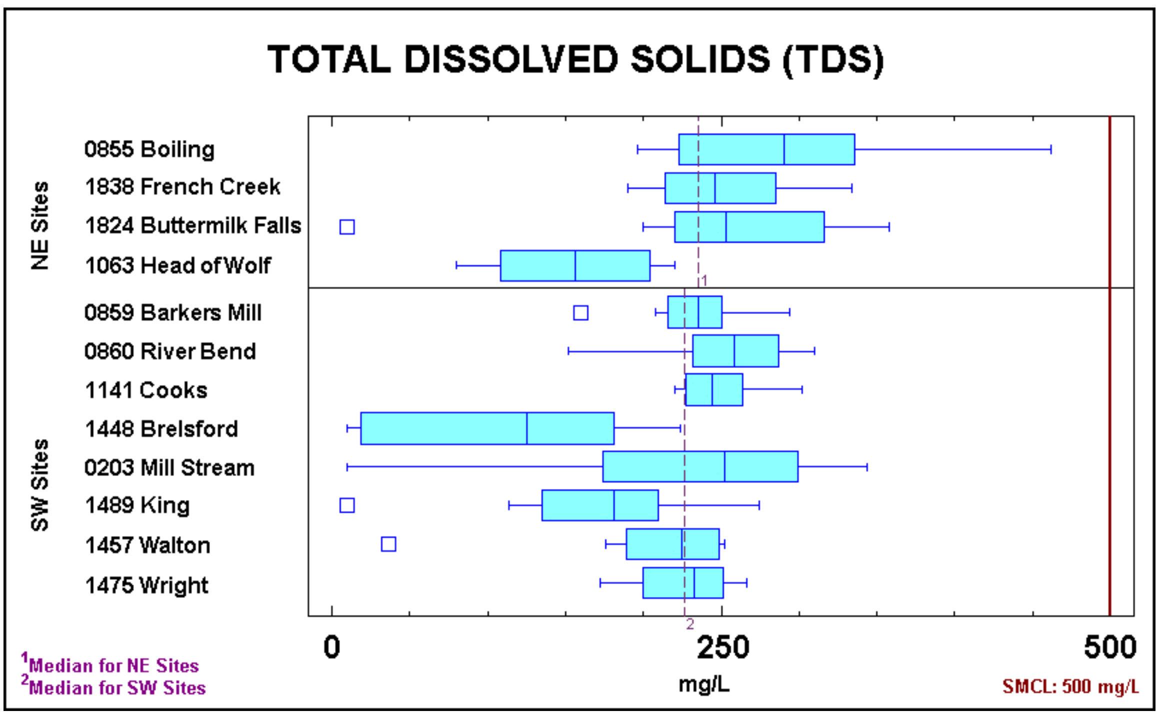


**Figure 44: Boxplot of Total Dissolved Solids (TDS) in Springs**

TDS was surprisingly low in the Mississippian Plateau, especially considering that this is soluble carbonate terrane. One possible explanation is that the quick flow characteristics of this region reduce the contact time between water and rock, thereby retarding dissolution. In general, TDS is not usually an important primary indicator of nonpoint source pollution of groundwater, although this parameter can serve as a surrogate indicative of general water quality. Because no probable sources for elevated TDS were noted adjacent to sampling sites, no nonpoint source impacts could be confirmed. Figure 44 shows higher values in the Boiling Springs Basin. These higher values are probably natural, perhaps resulting from longer residence times or dissolution of gypsum beds.

## Total Suspended Solids

Total Suspended Solids (TSS), also known as non-filterable residue, are those solids (minerals and organic material) that remain trapped on a 1.2 μm filter (EPA, 1998). Suspended solids can enter groundwater through runoff from industrial, urban, or agricultural areas. Elevated TSS (MMSD, 2002) can ". . . reduce water clarity, degrade habitats, clog fish gills, decrease photosynthetic activity and cause an increase in water temperatures." TSS has no drinking water standard.

Most TSS values occurred within a narrow range, but three elevated measurements, above 45 mg/L, did occur (Figure 45). Within most karst systems, turbidity and TSS vary with change in flow. However, poor management practices associated with activities such as construction and agricultural tillage can remove vegetation cover and allow the quick influx of sediment into karst groundwater via overland flow and internal runoff. Therefore, outliers in the karst of the Mississippian Plateau may represent nonpoint source impacts. However, in the case of Boiling Spring, which generally contained the highest TSS levels, no significant correlation was found between land use and TSS. Although impacts from construction activities and agricultural tillage may be considered transient, cumulative sediment deposition within conduit systems and surface drainage networks is clearly a detriment to the aquatic system.

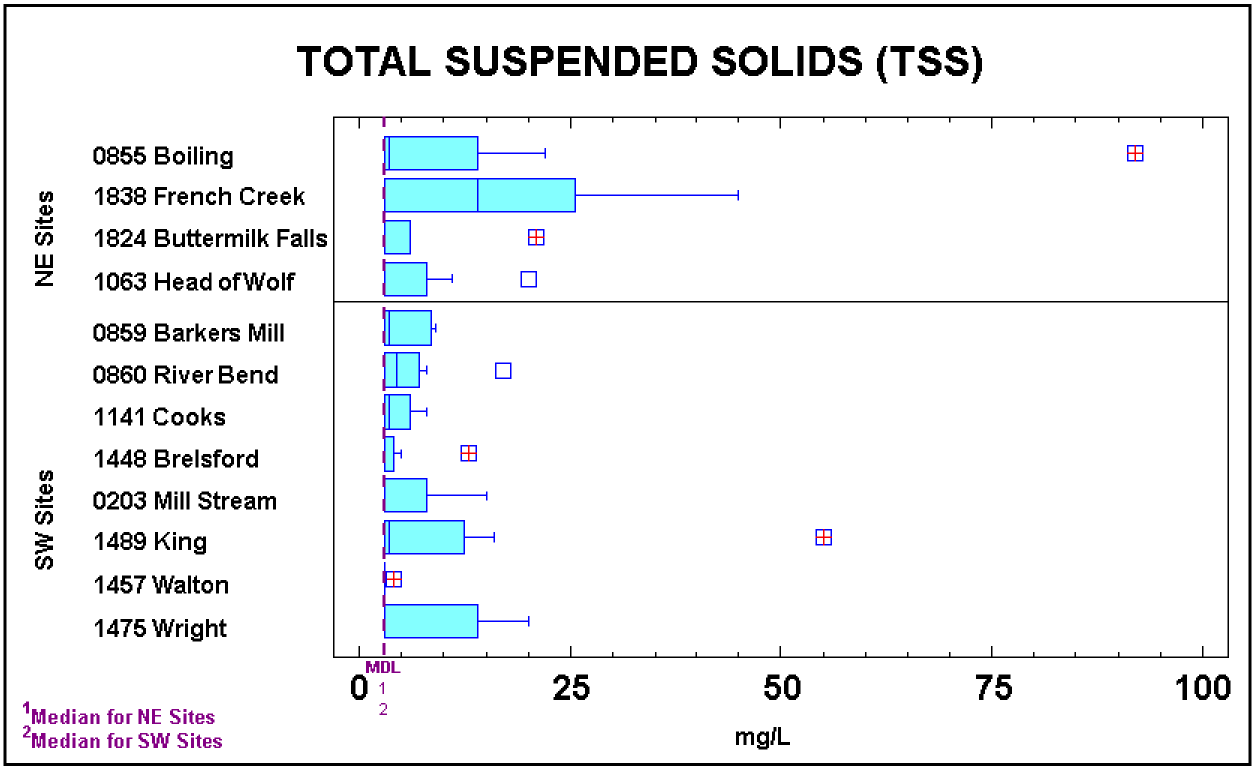


**Figure 45: Boxplot of Total Suspended Solids (TSS) in Springs**

## pH

pH is the negative log of the concentration of the hydrogen ion and is essentially a measure of the relative acidity or alkalinity of water. The units of pH are dimensionless, and the scale measures from 0 to 14. In this system, 7 represents neutral pH and values less than 7 are more acidic; values greater than 7 are more alkaline. The relative acidity/alkalinity of water is important in regard to water quality because this affects several qualities: the corrosiveness of the water, the ability to dissolve contaminants such as heavy metals, the taste of the water for human consumption and, in general, the overall usefulness of water for various industrial functions. The pH range of normal aquatic systems is between 6.5 and 8.0. Low pH levels can indicate nonpoint source impacts from coal mining or other mineral extraction processes. High pH values for groundwater may indicate nonpoint source impacts to groundwater from brine intrusion from current or former oil and gas exploration and development activities. For drinking-water supplies, pH is an aesthetic standard with an SMCL range of 6.5 to 8.5 pH units.

The greatest variability is in the southwest study area, with the median value at 7.35 and the outliers ranging from 6.75 to 8.15 pH units. The pH ranges tend to be slightly higher in the northeast study area, with a median value of 7.76. All values were within the SMCL range of 6.5-8.5 pH units (Figure 46). Buttermilk Falls precipitates tufa deposits, which indicate that the spring water is saturated with carbonate. This would account for the pH values at Buttermilk

Falls, which were generally higher than other sites. Consequently, no nonpoint source impacts can be interpreted from these pH data.

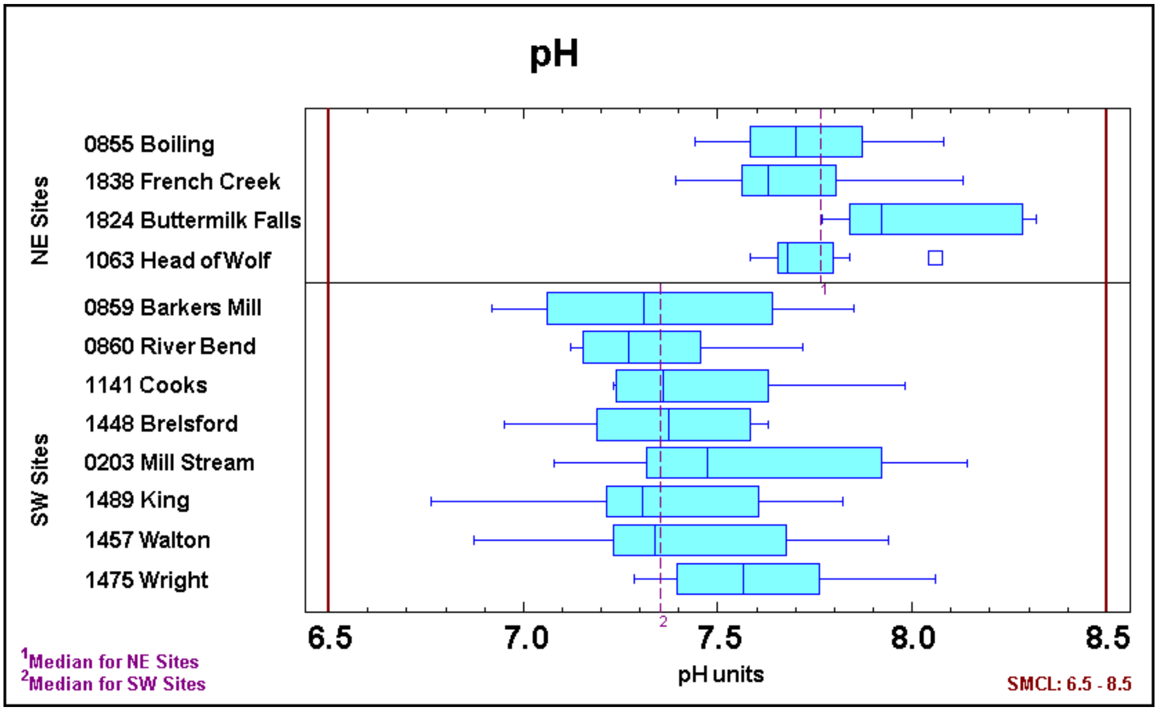


**Figure 46: Boxplot of Spring-Water pH**

## Chloride

Chloride (Cl) is naturally occurring in most rocks and soils and is the primary constituent that makes water "salty." Chloride also occurs in sewage, industrial brines and in urban runoff from the application of road de-icers. Chlorides may be associated with crude oil and are commonly produced as a by-product of oil production. For disposal, these brines are typically re-injected into very deep and already briny formations. However, chloride-rich brines can contaminate freshwater aquifers through improperly cased or abandoned oil-production wells. In general, the boxplots for chloride (Figure 47) shows low chloride values in the Mississippian Plateau Study areas. The SMCL for chloride is 250 mg/L and all the values for this study are 20 or more times less than the SMCL. Therefore, no apparent nonpoint source impacts can be interpreted from chloride data.

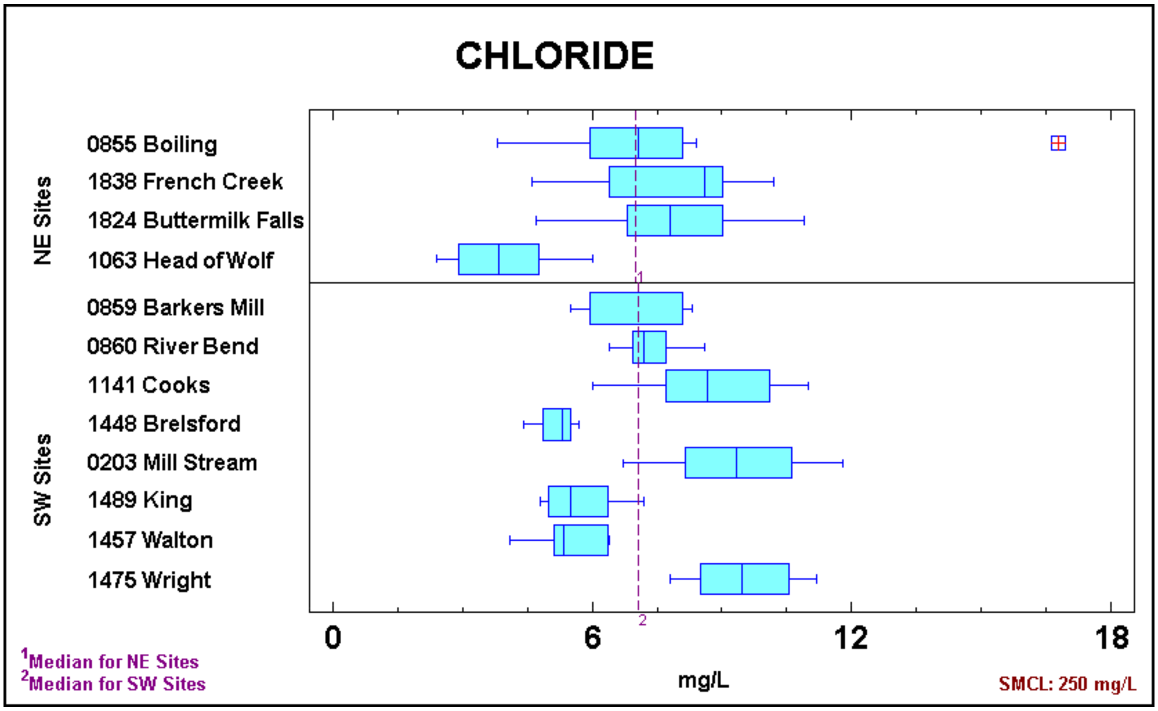


**Figure 47: Boxplot of Chloride Concentration in Springs**

## Sulfate

Sulfate ($SO_4$) typically dissolves into groundwater from gypsum (hydrous calcium sulfate) and anhydrite (calcium sulfate), from the oxidation of iron sulfides, such as pyrite (FeS) and from other sulfur compounds. Sulfate has an SMCL of 250 mg/L and greater levels impart distasteful odor and taste to the water and commonly have a laxative effect. In the project area, sulfate is common and naturally occurring, and therefore it is not easy to use as an indicator of nonpoint source pollution. In general, Figure 48 illustrates a narrow range of sulfate values, well under the SMCL.

The sulfate levels at Boiling Springs were the highest in this study but were still well below the SMCL. About 35% of Boiling Spring's basin includes sandstone caprocks, which may be a source of the relatively higher sulfate levels. Other springs with relatively higher sulfate include French Creek Spring and Head of Wolf Creek Spring in the NW, and Mill Stream Spring in the SW. Like Boiling Spring, these three springs also contain some sandstone rocks within their catchments.

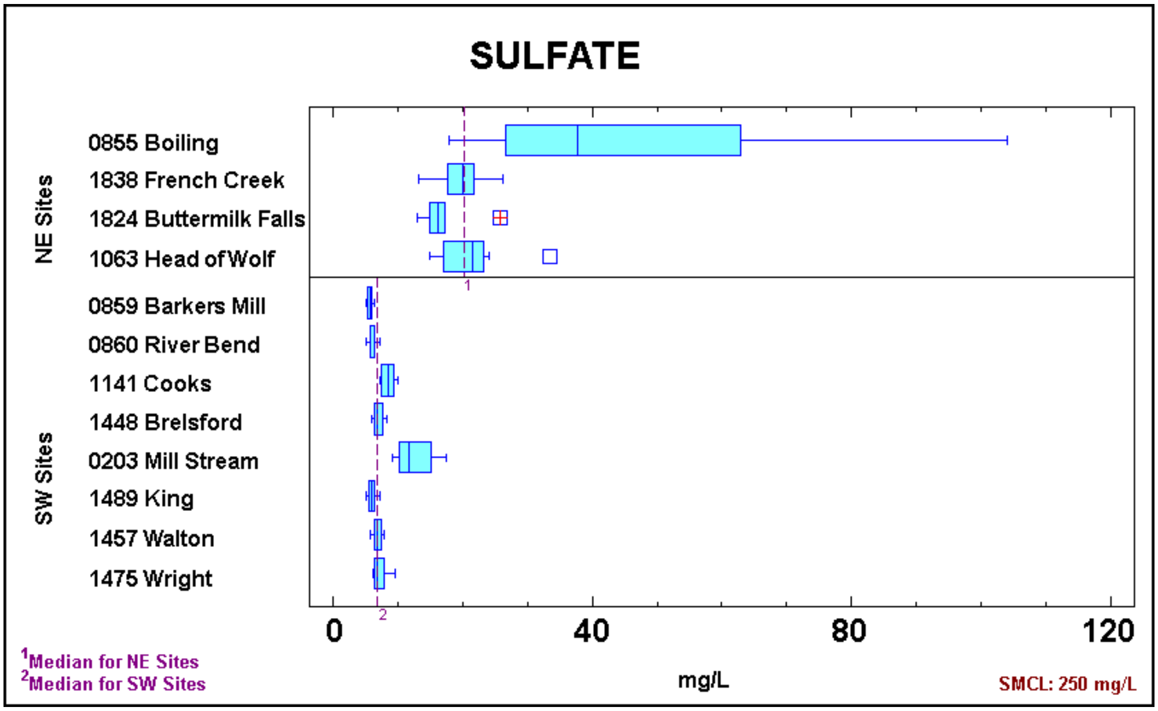


**Figure 48: Boxplot of Sulfate Concentration in Springs**

## Total Organic Carbon

Total organic carbon (TOC) is the measure of organic material in water. Organic matter plays a major role in aquatic systems. Organic matter in water consists of thousands of components, including macroscopic particles, colloids, dissolved macromolecules and specific compounds. It affects biogeochemical processes, nutrient cycling, biological availability, chemical transport and interactions. It also has direct implications in the planning of wastewater treatment and drinking water treatment. Organic matter content is typically measured as TOC and dissolved organic carbon, which are essential components of the carbon cycle.

Public water supplies can form trihalomethanes and haloacetic acids at unacceptable levels when they use chlorine to disinfect source waters with TOC levels above 4.0 mg/L. Most sample values were below the 4.0 mg/L value (Figure 49). One outlier at Boiling Springs from May, 2001, exceeded 22 mg/L. The source of this anomaly is unknown. Runoff from a livestock feedlot or manure spreading is a possible source of this relatively high TOC value.

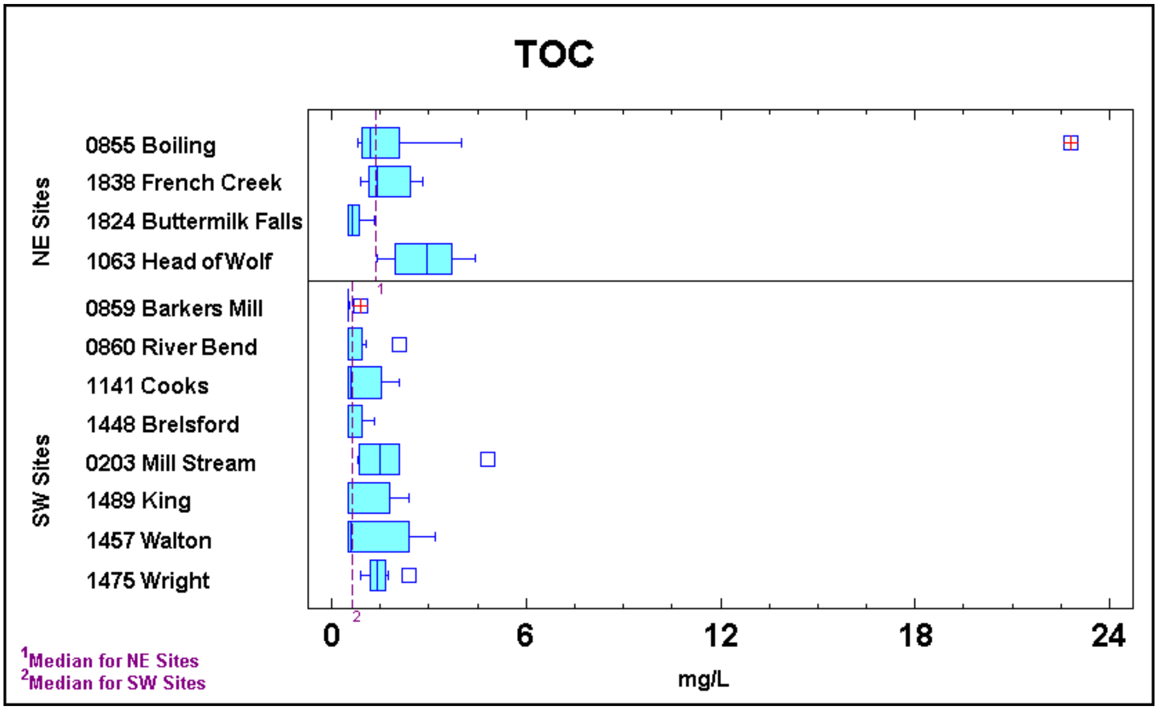


**Figure 49: Boxplot of Total Organic Carbon (TOC) in Springs**

***Pesticides***

Pesticides are not naturally occurring and are therefore good indicators of nonpoint source impacts to groundwater. The most common pesticide detected in spring waters of both study areas was atrazine. Low levels of acetochlor, metolachlor, simazine, alachlor and metribuzin were occasionally detected as well. These are all agricultural herbicides and are briefly described below.

**Atrazine**

According to Division of Pesticides agriculture sales data for 1999 and 2000, approximately two million pounds of atrazine were purchased for use in Kentucky during each of those years. Atrazine was the number one pesticide sold (by weight) in both years. Although sales data does not translate directly into use data, a significant amount of that two million pounds was used during the study period.

Atrazine is an odorless white powder made in a laboratory. Atrazine is not very volatile, reactive or flammable and is only moderately soluble in water. However, because atrazine does not adsorb strongly to soil particles and has a lengthy half-life (60 to >100 days), it has a high potential for groundwater contamination despite its moderate solubility in water. Atrazine is used on crops such as sugarcane, corn and sorghum, on evergreen tree farms and for evergreen forest regrowth. It has also been used to keep weeds from growing on both highway and railroad rights-of-way. Atrazine can be sprayed on croplands as a pre-emergent before crops start growing and after they have emerged from the soil. Some of the trade names of atrazine are Aatrex®, Aatram®, Atratol®, and Gesaprim®. The scientific name for atrazine is 6-chloro-N-ethyl-N'-(1-methylethyl)-triazine-2,4-diamine. Atrazine is a restricted-use pesticide, which means that it requires use by a certified pesticide applicator or under of the direct supervision of a certified applicator and strict records on its use and application are required (Ernest Collins, personal communication, 2002). The EPA has set an MCL value of 0.003 mg/L for atrazine in drinking water.

KGS analyzed for atrazine, using the nitrogen phosphorus detector (NPD) method, at a minimum detection limit (MDL) of 0.0003 mg/L. Atrazine was detected above the MDL in 26% of 95 samples. These detections only occurred in the April and May samples and are associated with infiltration and runoff recharge during the pesticide application season (Figure 50). Atrazine was detected above EPA's Maximum Contaminant Level (MCL) of 0.003 mg/L seven times at six springs (8% of the samples). Values near the MCL at two additional springs ranged between 0.00294 and 0.00299 mg/L. The highest level of atrazine was from Walton Spring at **0.0119** mg/L, almost four times the MCL. This was the only spring to exceed the MCL on two separate dates, in the spring of 1999 and 2000 (Table 5 and Figure 51). The DEP uses a risk-based standard for atrazine of 0.00067 mg/L. Atrazine was detected above the risk-based standard in 20 of 95 samples or 21%.

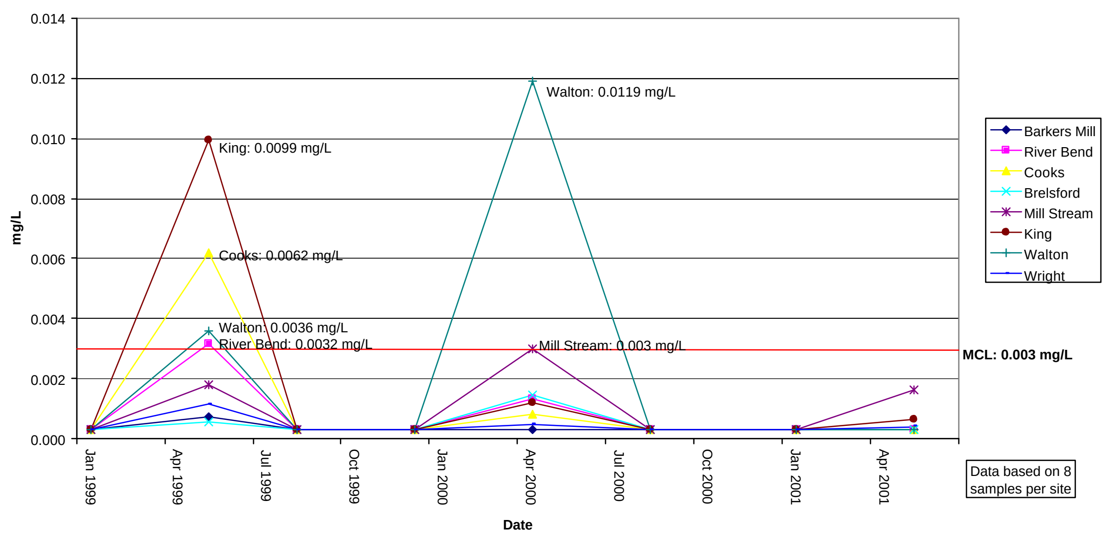


**Figure 50: Atrazine Concentration (mg/L) at Springs in SW Study Area, Showing Detections during Spring-Time Application Season**

| **Flow Condition** | Moderate | Moderate | Low | Low | Moderate | Low | Low | Moderate |
|---|---|---|---|---|---|---|---|---|
| **Sample Date** (SW) | **1/19/99 & 1/20/99** | **5/17/99 & 5/18/99** | **8/24/99 & 8/25/99** | **12/08/99 & 12/09/99** | **4/26/00 & 4/27/00** | **8/22/00 & 8/23/00** | **1/09/01 & 1/10/01** | **5/15/01 & 5/16/01** |
| ***Spring*** (SW) | | | | | | | | |
| *River Bend* | ND | **0.00315** | ND | ND | 0.00134 | ND | ND | ND |
| *Barkers Mill* | ND | 0.00074 | ND | ND | ND | ND | ND | ND |
| *Wright* | ND | 0.00115 | ND | ND | 0.00048 | ND | ND | 0.00041 |
| *Mill Stream* | ND | 0.00179 | ND | ND | 0.00299 | ND | ND | 0.00162 |
| *King* | ND | **0.00993** | ND | ND | 0.0012 | ND | ND | 0.00067 |
| *Cook* | ND | **0.00615** | ND | ND | 0.00083 | ND | ND | ND |
| *Walton* | ND | **0.00360** | ND | ND | 0.0119 | ND | ND | ND |
| *Brelsford* | ND | 0.00059 | ND | ND | 0.00145 | ND | ND | ND |

| **Sample Date** (NE) | **1/27/1999** | **5/11/1999** | **8/25/1999** | **12/1/1999** | **4/26/2000** | **8/23/2000** | **1/10/2001** | **5/15/2001** |
|---|---|---|---|---|---|---|---|---|
| ***Spring*** (NE) | | | | | | | | |
| *French Creek* | ND | **0.00675** | ND | ND | ND | ND | ND | ND |
| *Boiling* | ND | 0.00067 | ND | ND | ND | ND | ND | 0.55 |
| *Buttermilk Falls* | ND | **0.00393** | ND | ND | - | ND | 0.0012 | 0.00206 |
| *Head of Wolf* | ND | 0.00294 | ND | ND | ND | ND | ND | ND |

ND = Non-detection of atrazine (MDL = 0.0003 mg/L)
**Bold** values are above MCL of 0.003 mg/L

**Table 5: Atrazine Concentrations (mg/L) in Springs, 1999-2001**

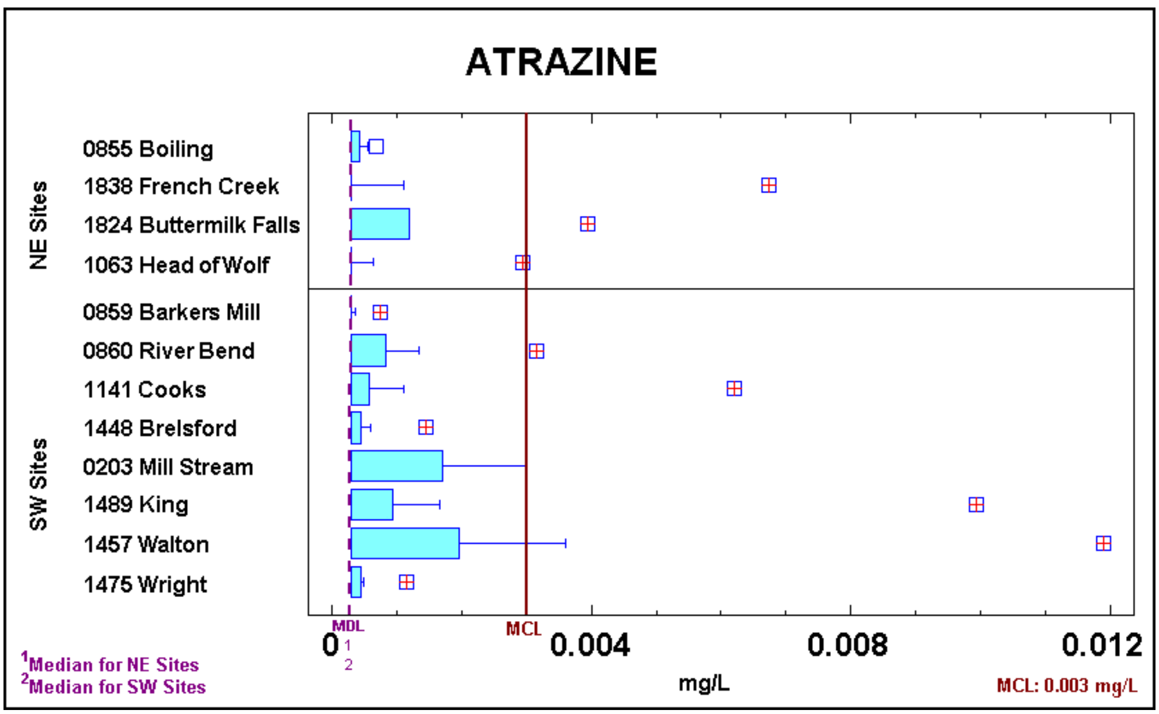


**Figure 51: Boxplot of Atrazine Concentration in Springs**

Pleasant Grove Spring in Logan County, Kentucky, which drains a hydrogeologic setting similar to the springs in the SW study area, was intensively sampled for nonpoint source contaminants during the early 1990s (Currens 1999). A low-level background of atrazine in the range of 0.00005-0.0003 mg/L was documented for this spring with the only non-detection occurring in February. Low levels of atrazine are likely to persist year-round in most karst springs draining agricultural basins where atrazine is applied (James Currens, personal communication, 2002). Halberg and others (1985), reported year-round levels of atrazine at or above 0.0002 mg/L at Big Spring in northeast Iowa.

A five-month study of eight karst springs in the Green River basin by the USGS (Crain, 2002) detected atrazine in 100% of 59 monthly samples at a low MDL of 0.000007 mg/L. Thirteen of 59 samples, or 22% of those samples, were above the KGS laboratory MDL value of 0.0003 mg/L (Angela Crain, personal communication, 2002), which is similar to 26% detection above 0.0003 mg/L in this study).

Quarterly samples (the design frequency of this study) obviously do not reveal the range of variation of pesticide concentration discharged by a karst spring. Currens (1999) showed that with monthly and storm event sampling, higher levels of atrazine are periodically flushed from karst springs draining agricultural basins. The highest atrazine value recorded at Pleasant Grove Spring was 0.028 mg/L (5-4-93) "during a major high-flow event following an extended dry period during planting season" (Currens, 1999). Inferring that similar karst will act the same hydrologically, the two studies above indicate that all karst springs in this study are discharging significant levels of atrazine during spring floods, possibly up to an order of magnitude above MCL during those brief periods, and these same springs are most likely discharging currently undetectable levels of atrazine on a continuing basis.

***Other Herbicides Detected***

### Acetochlor

Acetochlor is used for control of most annual grasses and certain broadleaf weeds. Crops include cabbage, corn (all types), cotton, green peas, onion, orchards, potatoes, rape, soybeans, sugarbeets, sugarcane, sunflower and vineyards. Acetochlor is applied pre-emergence, pre-plant incorporated and is compatible with most other pesticides and fluid fertilizers when used at recommended rates. Usually 0.3-0.6 inches of rainfall will activate the product if it occurs within 7-10 days. Acetochlor, like atrazine, is a restricted-use pesticide.

Acetochlor was the number five best seller on the Division of Pesticides List of Pesticides Sold during 1999 and number six in 2000. However, it was only detected once at Buttermilk Falls in the NE area in January of 2000.

### Metolachlor

Because of the slow microbial and anaerobic degradation rates of this chemical and its ability to leach through soil, metolachlor has the potential to contaminate groundwater. Trade names for products containing metolachlor include Bicep®, CGA-24705®, Dual®, Pennant® and

Pimagram®. The compound may be used in formulations with other pesticides (often herbicides that control broad leaved weeds) including atrazine, cyanazine and fluometuron.

Metolachlor was the number three best selling pesticide in Kentucky (by weight) in both 1999 and 2000. Approximately 800,000 pounds were sold in 1999 and approximately 650,000 pounds of the pesticide were sold during 2000. Although metolachlor was detected in 8.5% of the samples, none was detected at very high levels. Metolachlor does not have an MCL, but does have a HAL limit of 0.1 mg/L. None of the samples with metolachlor detections reached half of the HAL (0.05 mg/L). Only one sample from the NE study area contained metolachlor (Head of Wolf Spring during the May 1999 sampling event). The SW area, however, showed detections at five springs (River Bend, May '99; Cooks Spring, May '99; Mill Stream May '99 and May '01; King May '99; and Walton Spring May '99 and April '00) (Figure 51). The highest concentration detected was at Walton Spring in April of 2000 at 0.001901 mg/L.

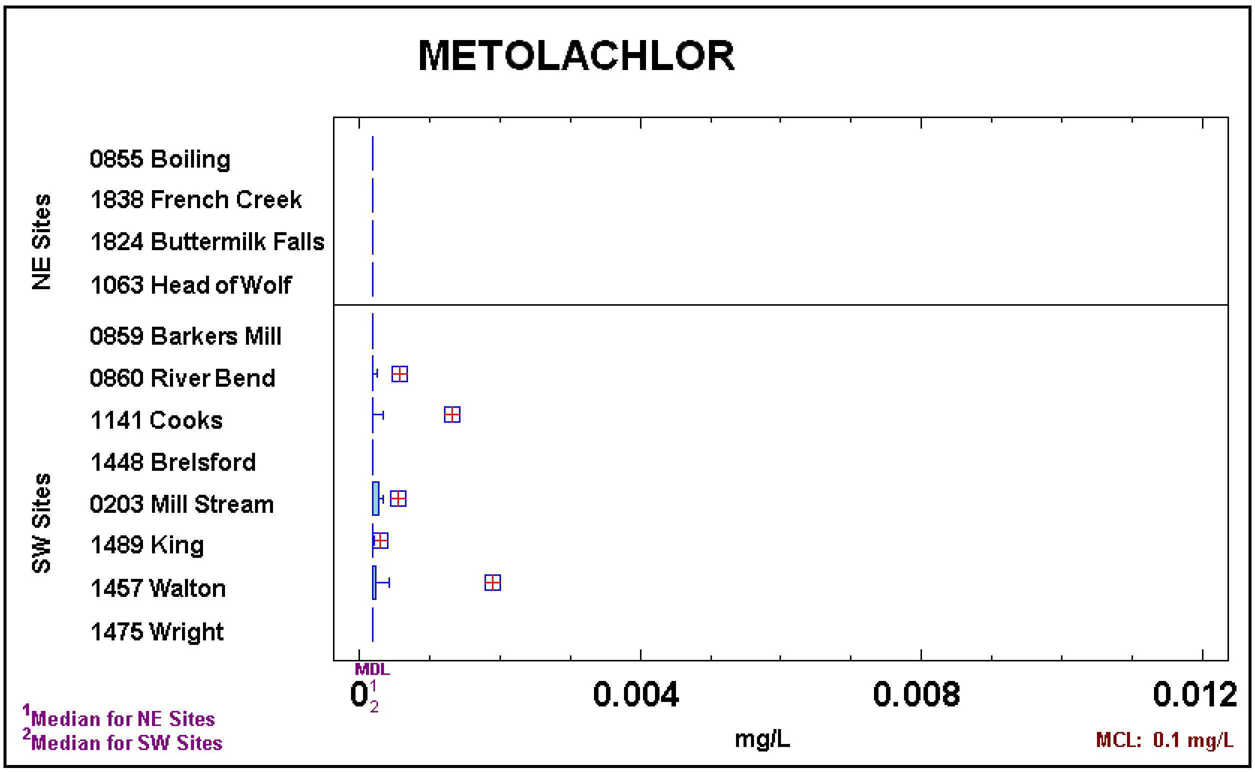


**Figure 52: Boxplot of Metolachlor Concentration in Springs**

## Simazine

Simazine is an organic white solid, used as a pre-emergence herbicide for control of broad-leaved and grassy weeds on a variety of deep-rooted crops such as artichokes, asparagus, berry crops, broad beans, citrus, etc., and on non-crop areas such as farm ponds and fish hatcheries. Its major use is on corn where it is commonly combined with Atrex® (which contains atrazine). The MCL for simazine is 0.0004 mg/L.

Simazine was detected in 11.5% of the samples, but none was detected above the MCL nor even above one-half the MCL. The highest concentration of simazine was detected at 0.0000016 mg/L in Mill Stream Spring in April of 2000 (it was also detected in May of 2001 at a lower concentration). Detections on more than one occasion occurred at other springs during the study period as well (Buttermilk Falls in May of ’99 and May of ’01; and River Bend in May ’99 and April ’00) (Figure 53). However, simazine was not detected in either study area as a persistent contaminant.

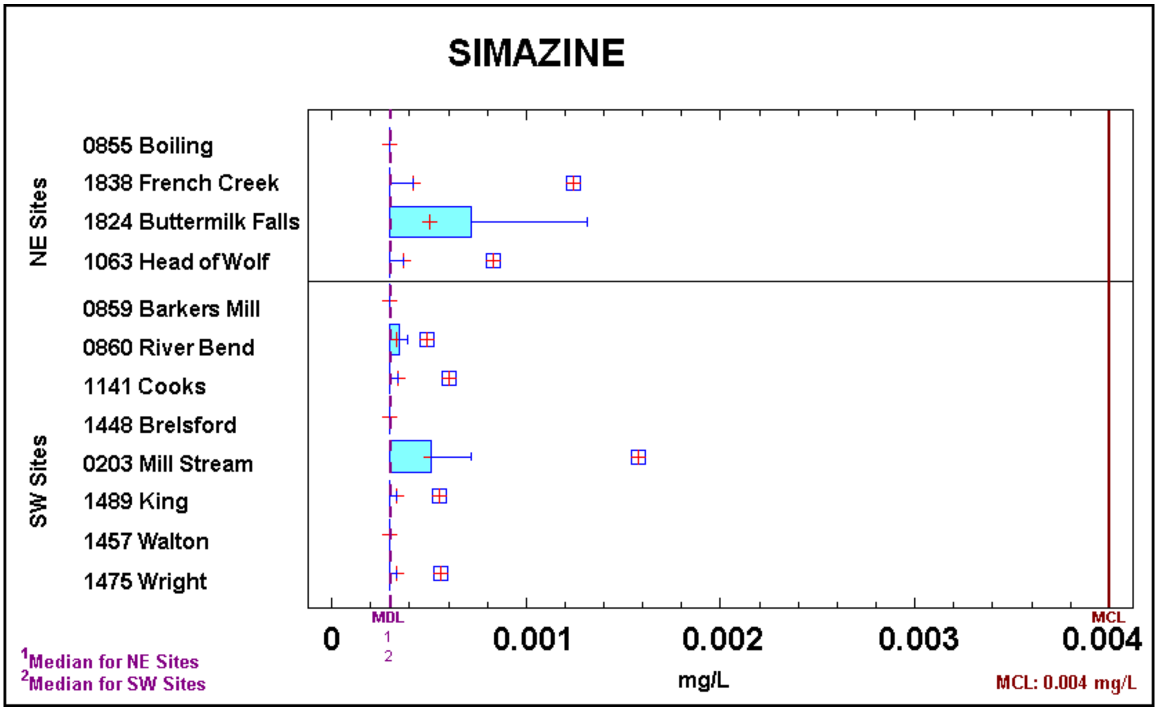


**Figure 53: Boxplot of Simazine Concentration in Springs**

## Metribuzin

Metribuzin is a selective triazinone herbicide, which inhibits photosynthesis. It is used for control of annual grasses and numerous broadleaf weeds in field and vegetable crops, in turf grass and on fallow lands. Metribuzin is highly soluble in water and has a low tendency to adsorb to most soils. Metribuzin is considered to be one of a group of pesticide compounds that has the greatest potential for leaching into, and contaminating, groundwater. Metribuzin was only detected once at Wright spring in the SW study area (5-18-99), just above the MDL. The high solubility of metribuzin and only a single detection in this study indicate that metribuzin is not likely to contaminate groundwater for long periods of time. Pulses of water coming through the system as a result of a rain event may wash some unmetabolized metribuzin into the groundwater, however.

### Alachlor

Alachlor (trade names include Bullet® and Micro-Tech®) is used for corn and soybean production for pre-emergent weed control. Alachlor has an MCL of 0.002 mg/L. Alachlor has been associated with cancer in humans and has also been linked with noncancerous effects in the liver, spleen and kidneys. Alachlor occurred at only one site in this study and it was well below the MCL. Alachlor was found at Buttermilk Falls in the NE study area. Based upon its limited occurrence, alachlor has apparently had minor impacts on groundwater in this area.

***Summary Statistics***

A tabular summary of water quality analyses is provided in Appendix C. The initial table lists 16 *parameters* with *applicable water quality standards*. This table also provides *Total Number of Samples, Samples <MDL, Samples With Detects, Detects >Standard* and *Detects >1/2 Standard.* For each parameter, *Minimum, Median, Maximum* and *Interquartile Range* are provided for individual springs, including study totals. Also, totals are separately provided for the NE and SW study areas.

## RANKING OF NONPOINT SOURCE POLLUTION IN SPRING BASINS

We propose that the following approach be used to address NPS issues in karst systems. The 12 sampled karst springs were ranked and prioritized based on water quality and land use. These rankings were based on 12 weighted parameters. A weighted average was calculated by assigning weights to each parameter according to its relative importance in generating nonpoint source pollution. Since metolachlor, simazine and alachlor were detected minimally during the study, their combined importance was considered equivalent to that of the other water quality parameters. Thus, they were assigned 1/8th (or 5/40) of the importance, divided among the three (or 2/40, 2/40 and 1/40). The other five water quality parameters were assigned ranks of relative importance equivalent to 1/8th. The eight water quality components included: atrazine (5/40), metolachlor (2/40), simazine (2/40), alachlor (1/40), nitrate-N (5/40), orthophosphate (5/40), total organic carbon (5/40) and total suspended solids (5/40).

Four land-use components included: row crops (6/40), pasture and hay (4/40), urban (2/40) and forest (-2/40). Because both nutrients and pesticides may be applied to row crops, it was considered the highest-rated land-use component, whereas pasture and hay could be considered a less intensive land use. Urban/residential land use is minimal in the predominantly rural study areas. The only basin to exceed 3% of this type land use was Buttermilk Falls Spring with 5.1%. Even though urban runoff can yield significant nonpoint source pollution, it was ranked low because of minimal spatial occurrence in the two study areas. Forest is the only land use to be expressed with a negative weighting, which lowers the priority rating relative to nonpoint source pollution. Karst basins with greater forested land cover typically exhibit the best water quality, Brelsford Spring for example. The above criteria are organized by class in Table 6.

| Weight | Class | Individual Parameter Weights |
|---|---|---|
| 10/40 | Pesticides | Atrazine (5); Metolachlor (2); Simazine (2); Alachlor (1) |
| 10/40 | Nutrients | Nitrate-N (5); Ortho-P (5) |
| 10/40 | Other Parameters | Total Organic Carbon (5); Total Suspended Solids (5) |
| 10/40 | Land Use | Row Crop (6); Pasture & Hay (4); Urban (2); Forest (-2) |

**Table 6: Criteria for Karst Basin Priority Ranking**

Average ranks yielded from the Kruskal-Wallis test (Hollander and Wolfe, 1973) were used to assign ranks for the springs from smallest to largest based on concentrations of the parameters considered as well as type and percentage of land use. These 12 average parameter ranks were then weighted and summed for each spring, and the sums ordered from highest to lowest. An overall ordinal ranking for water quality, based on concentration and land use, was assigned to each spring according to the spring's position in this ordering with **1** indicating the highest priority (poorest water quality), and **12** indicating the lowest priority (best water quality). The relative weighted-value scores are shown for each spring in Table 7.

| Rank | Spring | | Weighted Value |
|---|---|---|---|
| | Southwest | Northeast | |
| **1** | River Bend | | 9.15 |
| **2** | Wright | | 8.83 |
| **3** | Mill Stream | | 7.83 |
| **4** | King | | 7.53 |
| **5** | Cooks | | 7.10 |
| **6** | Barkers Mill | | 6.88 |
| **7** | | French Creek | 6.88 |
| **8** | Walton | | 6.53 |
| **9** | | Boiling | 5.68 |
| **10** | | Buttermilk Falls | 4.05 |
| **11** | | Head of Wolf | 4.00 |
| **12** | Brelsford | | 3.58 |

**Table 7: Nonpoint-Source Pollution Priority Ranking of Twelve Sampled Karst Springs**

### *Correlation of Water Quality of Springs with Land Cover*

#### Nitrate-N

The distribution of nitrate-N concentration was nearly normally distributed (Shapiro-Wilk (w) = 0.97, p = 0.0272). The strong positive correlation between nitrate-N concentration and percentage of agricultural land was significant (Pearson correlation coefficient (r) = 0.81, p <

0.0001). The relationship between nitrate-N concentration and percentage of row crop land use ($r = 0.80$, $p < 0.0001$) was stronger than that between nitrate-N concentration and percentage of pasture land ($r = 0.55$, $p < 0.0001$). The strong inverse relationship between nitrate-N concentration and percentage of forested land was also significant ($r = -0.81$, $p < 0.0001$). Regionally, stronger positive correlations between nitrate-N concentration and percentage of agricultural land were observed in the NE region ($r = 0.74$, $p < 0.0001$) than in the SW region ($r = 0.64$, $p < 0.0001$).

In the NE region, correlation between nitrate-N concentration and percentage of pasture land ($r = 0.71$, $p < 0.0001$) was stronger than that between nitrate-N concentration and percentage of row crop land use ($r = 0.61$, $p = 0.0002$). A strong inverse relationship between nitrate-N concentration and forested land ($r = -0.81$, $p < 0.0001$) was also observed.

In the SW region, a moderate positive correlation was observed between nitrate-N concentration and agricultural land ($r = 0.64$, $p < 0.0001$), while a moderate inverse relationship was observed between nitrate-N concentration and forested land ($r = -0.63$, $p < 0.0001$). A moderate positive correlation between row crop land use ($r = 0.64$, $p < 0.0001$) was observed, but no significant correlation between nitrate-N concentration and pasture land existed in this region.

Regression analysis showed that 65% of the variability in nitrate-N concentration in the entire study area (NE and SW combined) could be attributed to agricultural land use ($R^2 = 0.65$, $p < 0.0001$), 64% attributed to row crop usage ($R^2 = 0.64$, $p < 0.0001$) and 67% to forested land ($R^2 = 0.67$, $p < 0.0001$). Regionally, 55% of the variability in nitrate-N concentration in the NE region could be attributed to agricultural land use ($R^2 = 0.55$, $p < 0.0001$), 50% attributed to pasture land ($R^2 = 0.50$, $p < 0.0001$) and 65% to forested land ($R^2 = 0.65$, $p < 0.0001$). 41% of the variability in nitrate-N concentration in the SW region could be attributed to agricultural land use ($R^2 = 0.41$, $p < 0.0001$), and 41% attributable to row crop land use ($R^2 = 0.41$, $p < 0.0001$).

**Ortho-P**

The distribution of ortho-P concentration was nearly normally distributed (Shapiro-Wilk ($w$) = 0.93, $p = 0.0346$). The strong positive correlation between ortho-P concentration and percentage of agricultural land was significant (Pearson correlation coefficient ($r$) = 0.64, $p < 0.0001$). The relationship between ortho-P concentration and percentage of pasture land ($r = 0.63$, $p = 0.0000$) was stronger than that between ortho-P concentration and percentage of row crop land use ($r = 0.48$, $p = 0.0051$). The strong inverse relationship between ortho-P concentration and percentage of forested land was also significant ($r = -0.63$, $p = 0.0001$). Regionally, stronger positive correlations between ortho-P concentration and percentage of agricultural land were observed in the NE region ($r = 0.74$, $p < 0.0001$); no significant correlation between ortho-P concentration and agricultural land existed in the SW region.

Because of the numerous non-detections of atrazine, it could not be correlated with land use.

### *Use of Agricultural Best Management Practices to Limit and Reduce Nonpoint Source Pollution*

This study has shown that karst groundwater drainage is especially sensitive to agricultural nonpoint-source pollution. However, Kentucky's Agricultural Water Quality Plan (1996) describes numerous best management practices (BMPs) that have been developed to help limit and reduce soil erosion and the rapid leaching or runoff of nutrients and pesticides. Below is a list of key BMPs:

- Avoid applying pesticides when heavy rain is forecast. Runoff of chemicals reduces their usefulness and is expensive, as well as polluting to groundwater and streams.

- Read application instructions before using any pesticide and review each season. Follow setbacks and required buffers under "Environmental Hazards" section.

- Employ soil-testing on row-crop acreage and apply only the nutrients required (precision farming). Analyze animal waste prior to land application to formulate application rates.

- Utilize conservation cropping systems that include crop rotations, cover crops, conservation tillage technologies and buffer strips. Cover crops are especially effective on sloping land to control soil erosion and promote filtering of sediment and soil-borne pollutants.

- Limit manure spreading to the growing season when it is most effectively exploited by crops to avoid polluted runoff during winter rains. Avoid spreading manure on frozen or snow-covered land.

- Seek and test alternative pesticides that are less harmful to desirable plants, animals and aquatic organisms.

- Maintain and expand grassed buffer strips along drainage-ways and around sinkhole drains. Maintain sod in swales and shallow drainage channels within row-crop fields.

- Whenever possible, fence livestock from waterways and open sinkhole drains and use improved stream-crossing methods and stock-activated watering pumps.

- Locate livestock water troughs, mineral blocks, cattle rubs and shade loafing areas away from sinkhole drains and waterways.

- Encourage maintenance and expansion of forested land cover and vegetated fence-row belts. Limit disturbance of swamps, marshes and riparian areas.

- Consider seeding marginal areas in native vegetation to encourage wildlife and expand vegetated buffers.

## Conclusions

Karst landscapes located in Kentucky's Mississippian-aged rocks are especially sensitive to nonpoint pollution from agriculture, urban development and transportation corridors. The region's karst drainage is vulnerable to pollution because of rapid preferential drainage via soil macropores, sinkholes and solution conduits. Also, the hidden underground nature of karst drainage tends to impede research and knowledge about this important resource. The Pennyroyal Plateau of western and central Kentucky is primarily an intensive agricultural region. These important economic activities can generate serious nonpoint-source (NPS) pollution of the vital groundwater resources of the region.

In order to identify, evaluate and help mitigate impacts from nonpoint source pollution in the region's water systems, this five-year field study investigated 12 karst springs in two study areas within the Pennyroyal Plateau. The research methodology included the following:

(a) Extensive hydrogeologic field reconnaissance, literature and research survey, and numerous professional and landowner contacts were completed.

(b) A total of 42 groundwater tracer tests were conducted in both areas and 261 km (162 mi) of subsurface flow routes within 19 groundwater basins were mapped for the first time or replicated. These basins represent total land areas of 670 $km^2$ (258 $mi^2$) and base-flow water supply of 850 L/s (30 $ft^3/s$).

(c) Discharge of 32 large springs was measured during dry-season base flow conditions in order to assess aquifer yield and evaluate basin delineations through unit base flow calculations.

(d) Ninety-six quarterly groundwater samples were collected at 12 representative springs from January 1999 through May 2001 to determine water chemistry and water quality.

(e) Based on the delineated spring basins, digital land-cover data were evaluated in order to quantify agricultural land use.

(f) Based on analysis of water-quality results and land use, springs (and their identified basins) were ranked and prioritized so that NPS resources could be applied to watersheds with the greatest needs.

Results of this research generated the following major conclusions about the study areas:

(1) Groundwater tracer testing is the only practical method to delineate karst drainage basins. This information is essential in order to attribute nonpoint-source pollutants within a landscape to the correct receiving spring. Topographic divides and potentiometric surface maps can also be used to estimate recharge areas of springs; however, estimates derived by these methods should be verified by tracer testing.

(2) Assessing the aquifer yield (base flow per unit area) is useful to understand hydrogeologic variations and support basin delineations. Springs were gaged in both study areas from 1997-2001, resulting in the following conclusions:

   (a) A direct relationship exists between base-flow discharge and basin area, within uniform hydrogeologic settings. However, UBF in the SW study area is 25%-30% greater than in comparable areas of the NE. This is likely due to slightly higher rainfall and increased groundwater storage within thicker soils of the SW study area.

   (b) Within the NE study area, basins typified by sinkhole-plain topography yielded twice the UBF as did basins draining dissected sandstone caprock. This is a consequence of greater sustained groundwater storage in soil-mantled limestone than in sandstone-capped plateaus.

(3) Most springs in the study areas are moderately contaminated by nitrate-N from agriculture, with medians ranging from about 1-6 mg/L. The highest concentrations were recorded at Wright Spring (7.05 mg/L) and River Bend Spring (6.85 mg/L). These concentrations approached but did not exceed the MCL of 10 mg/L.

(4) The herbicide atrazine is a persistent contaminant in karst groundwater, especially in the spring application season. Atrazine was detected above the MDL of 0.0003 mg/L in 26% of 95 samples. Atrazine was detected above the MCL of 0.003 mg/L seven times at six springs (7% of the samples). The highest concentrations were recorded at Walton Spring (0.0119 mg/L) and King Spring (0.00993 mg/L). Water samples were collected quarterly; continuous monitoring would certainly have revealed much higher maximum levels of atrazine in springs.

(5) The SW study area exhibits greater NPS pollution from agriculture than does the NE study area. This difference is primarily due to the intense agriculture in the more arable SW and greater forested land in the more dissected NE. Consequently, the higher priority ranking of springs tended to include most of the basins in the SW study area.

| ID # | Spring | Discharge L/s* | Basin Area $km^2$ | % Agri. | % Forest | Maximum Nitrate-N mg/L | Maximum Atrazine mg/L[B] | Weighted Score | Priority Rank |
|---|---|---|---|---|---|---|---|---|---|
| 0860 | River Bend | 158.6 | 69.9[m] | 87.7 | 8.7 | 6.19 | **0.00315** | 9.15 | **1** |
| 1475 | Wright | 25.5 | 14.2 | 89.7 | 6.2 | 7.05 | 0.00115 | 8.83 | **2** |
| 0203 | Mill Stream | 82.1 | 182.1[m] | 73.8 | 21.9 | 6.73 | 0.00299 | 7.83 | **3** |
| 1489 | King | 59.5 | 28.2 | 85.2 | 11.5 | 4.81 | **0.00993** | 7.53 | **4** |
| 1141 | Cook | 93.4 | 41.7[m] | 75.3 | 17.1 | 5.49 | **0.00615** | 7.10 | **5** |
| 0859 | Barkers Mill | 169.9 | 69.2[m] | 93.0 | 3.0 | 6.19 | 0.00074 | 6.88 | **6** |
| 1838 | French Creek | 45.3 | 54.4 | 67.9 | 27.2 | 3.59 | **0.00675** | 6.88 | **7** |
| 1457 | Walton | 48.1 | 25.1 | 77.4 | 19.0 | 6.24 | **0.0119** | 6.53 | **8** |
| 0855 | Boiling | 277.5 | 327.6 | 52.7 | 45.6 | 3.03 | 0.00067 | 5.68 | **9** |
| 1824 | Buttermilk Falls | 22.7 | 12.7 *est* | 26.8 | 65.1 | 2.21 | **0.00393** | 4.05 | **10** |
| 1063 | Head of Wolf Cr | 14 *est* | 42.5 | 27.9 | 70.1 | 1.04 | 0.00294 | 4.00 | **11** |
| 1448 | Brelsford | 85 *est* | 32.9 | 65.4 | 31.1 | 2.64 | 0.00145 | 3.58 | **12** |

**Table 8: Summary of Numerical Data Derived by this Investigation.**
(*Discharge during dry-season base-flow conditions; [m] Basin areas have been modified by subsequent research; [B] Bold font indicates atrazine concentration above MCL)

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# APPENDIX A: FINANCIAL AND ADMINISTRATIVE CLOSEOUT

## 1. Work Plan Outputs

### Milestones

| | | |
|---|---|---|
| 1. | Preliminary work | Completed |
| 2. | Initial spring reconnaissance, discharge measurements, and 1st quarter monitoring | Completed |
| 3. | 2nd quarter monitoring | Completed |
| 4. | 3rd quarter monitoring | Completed |
| 5. | 4th quarter monitoring | Completed |
| 6. | 5th quarter monitoring | Completed |
| 7. | 6th quarter monitoring | Completed |
| 8. | 7th quarter monitoring | Completed |
| 9. | Basin delineations completed | Completed |
| 10. | 8th quarter monitoring | Completed |
| 11. | Karst education agriculture outreach | Continuing |
| 12. | Land use analyses completed | Completed |
| 13. | Develop karst groundwater basin nonpoint source ranking scheme | Completed |
| 14. | Prepare Ranking and Monitoring Report | Completed |

## 2. Budget

| Budget Categories | Section 319(h) | Non-Federal Match | Total | Final Expenditures |
|---|---|---|---|---|
| **Personnel** | $11,216 | $40,480 | $51,696 | $51,696 |
| **Supplies** | | | | |
| **Equipment** | | | | |
| **Travel** | | | | |
| **Contractual** | $49,504 | | $49,504 | $49,504 |
| **Operating Costs** | | | | |
| **Other** | | | | |
| **TOTAL** | $60,720 | $40,480 | $101,200 | $101,200 |
| | 60% | 40% | 100% | |

The Groundwater Branch of the Kentucky Division of Water was reimbursed $60,720. All dollars were spent; there were no excess project funds to reallocate.

## 3. Equipment Purchased.

No equipment was purchased for this project.

## 4. Special Grant Conditions.

No special grant conditions were placed on this project.

This project did involve contractual activity which included a contract with the Kentucky Geological Survey for sample analysis. The DOW/KGS contract is attached.

**MEMORANDUM OF AGREEMENT**

**between the**

**COMMONWEALTH OF KENTUCKY**

**NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION CABINET**

**DEPARTMENT FOR ENVIRONMENTAL PROTECTION**

**DIVISION OF WATER**

**and the**

**UNIVERSITY OF KENTUCKY RESEARCH FOUNDATION**

**for the**

**KENTUCKY GEOLOGICAL SURVEY**

**SUBJECT: IDENTIFICATION AND PRIORITIZATION OF KARST GROUNDWATER BASINS IN KENTUCKY FOR TARGETING RESOURCES FOR NONPOINT SOURCE POLLUTION PREVENTION AND ABATEMENT - ANALYTICAL SERVICES**

**Kentucky Nonpoint Source Management Program**

**July 1, 1998**

This Memorandum of Agreement, made and entered into by and between the Commonwealth of Kentucky, Natural Resources and Environmental Protection Cabinet, Department for Environmental Protection, Division of Water, (hereinafter "Division of Water" or "DOW"), and the University of Kentucky Research Foundation for the Kentucky Geological Survey (hereinafter "recipient").

WITNESSETH:

**WHEREAS**, the Commonwealth of Kentucky is charged with the implementation of the Kentucky Nonpoint Source Management Program as required by Section 319 of the federal Clean Water Act Amendments of 1987; and

**WHEREAS**, control of nonpoint source pollution through water quality assessment is an important component of the Kentucky Nonpoint Source Management Program; and

**WHEREAS**, the Division of Water, as the lead oversight agency for the Kentucky Nonpoint Source Pollution Control Program, implements the Program primarily through the activities of cooperating agencies, institutions, and organizations; and

**WHEREAS**, part of the mission of the recipient is activities involving water quality assessment; and

**NOW, THEREFORE**, in consideration of the mutual covenants expressed herein, DOW and the recipient hereby AGREE as follows:

## I. INTRODUCTION

The Division of Water, as the lead oversight agency for the Kentucky Nonpoint Source Pollution Control Program, developed a Section 319(h) Kentucky Nonpoint Source Implementation Grant Workplan for Federal Fiscal Year (FFY) 1997. The Workplan describes projects that will partially implement the Kentucky Nonpoint Source Management Program. Subsequently, the U.S. Environmental Protection Agency (EPA) approved the Workplan and, to enable implementation of the projects described therein, awarded a grant to the Division of Water through the Section 319(h) Nonpoint Source Implementation Program Cooperative Agreement (#C9994861-97) for FFY 1997, which is subject to the terms and conditions of the approved Workplan. This Memorandum of Agreement assigns implementation of one of the Workplan projects, "Identification And Prioritization Of Karst Groundwater Basins In Kentucky For Targeting Resources For Nonpoint Source Pollution Prevention And Abatement - Analytical Services" to the recipient.

Introduction to the Project:

The objectives of this study are as follows: (1) spring monitoring samples will be delivered to the recipient laboratory for analysis. Analytical results will be delivered to the Groundwater Branch by the recipient laboratory on a quarterly basis.; (2) produce additional water quality assessment data that will augment groundwater monitoring efforts conducted by the Division of Water, the Division of Pesticides, the Kentucky Geological Survey, the U.S. Geological Survey and the Departments of Agriculture and Agronomy at the University of Kentucky

## II. SCOPE OF SERVICES

The recipient shall comply with the terms and conditions as follows:

**Section A. Identification And Prioritization Of Karst Groundwater Basins In Kentucky For Targeting Resources For Nonpoint Source Pollution Prevention And Abatement - Analytical Services**

Plan of Work:

The recipient shall conduct this plan of work as follows:

1. Receive samples delivered by the DOW at a maximum of twelve (12) samples per quarter. Each sample will be accompanied by a Chain-of-Custody (COC) form completed by the DOW which shall serve as the instructions for the analyses required. The recipient shall maintain the custody and integrity of each of the samples at all times and shall store the unused portion of each sample for a period of three (3) months after the sample collection date.

2. The recipient shall perform one or more of the following tasks as defined by the COC for each sample. These tasks include:

a. The preparation of water samples for all laboratory analyses.
b. Analyze the prepared samples for the constituents listed in Attachment I.

**Section B. Outputs**

The recipient shall:

1. Report the analytical data to the DOW in a format suitable for electronically loading into the DOW's Consolidated Groundwater Database, and in hard copy to include the completed analyses together with the documentation necessary to validate the results. Reports shall be submitted to the DOW within sixty (60) days of receipt of each sample.

2. Provide quarterly invoices for personnel costs and all completed samples that have been analyzed during the quarter.

**Section C. Quality Assurance/Quality Control Plan**

The recipient shall ensure that all water quality monitoring activities in this Agreement shall be conducted in accordance with the approved Quality Assurance/Quality Control Plan. The approved Quality Assurance/Quality Control Plan shall be incorporated into this Agreement by reference.

**Section D. Reporting Requirements**

Records Retention Requirement: The recipient shall retain all financial records, supporting documents, accounting books and other evidence of assisted activities including federal and non-federal matching funds until December 31, 2009. If any litigation, claim or audit is started prior to this expiration date, the recipient must maintain all appropriate records until these actions have been completed and all issues have been resolved.

## III. METHOD OF PAYMENT

This Agreement shall be funded by an award from EPA to the Division of Water through 319(h) Nonpoint Source Implementation Program Cooperative Agreement #C9994861-97, CFDA 66.460. The total project cost shall not exceed forty nine thousand five hundred four and dollars ($49,504).

Under this cost reimbursement contract, the recipient shall invoice DOW for all costs associated with the project on a quarterly basis. DOW shall reimburse the federally funded portion, one hundred percent (100.00%), of the total project cost. The total reimbursement is not to exceed forty nine thousand five hundred and four dollars ($49,504) in accordance with this Agreement. The recipient shall submit quarterly invoices with an attached NPS Project Progress Report to the Division of Water, Nonpoint Source Section. The recipient shall submit the final invoice with attached Final Report, Project Close Out Report, and project documentation to the Division of Water, Nonpoint Source Section. Payment of the final invoice is subject to Environmental Protection Agency approval.

## IV. ASSURANCES

A. The recipient shall comply with: (1) Office of Management and Budget Circular Nos. A-21, A-110, and A-133; and (2) applicable provisions of Standard Form 424B, Assurances - Non-construction Programs, all of which are incorporated into this Agreement by reference.

B. The recipient shall comply with the following award conditions specified in 319(h) Nonpoint Source Implementation Program Cooperative Agreement #C9994861-97, CFDA #66.460: (1) The recipient must ensure to the fullest extent possible that at least an 8% minimum MBE/WBE (minority business enterprises/women's business enterprises) goal of Federal funds for prime or subcontracts for supplies, construction, equipment, or services are made available to organizations owned or controlled by socially and economically disadvantaged individuals, women, and historically black colleges and universities. The recipient agrees to include in its bid documents this 8% minimum goal and require all of its prime contractors to include in their bid documents for subcontracts the negotiated "Fair Share" percentage. To evaluate compliance with the "Fair Share" policy, the recipient agrees to comply with P.L. 102-389, the six affirmative steps stated in 40 CFR 33.44(b), 31.36(e), or 35.6580(a) as appropriate. (2) In accordance with Section 129 of Public Law 100-590, the Small Business Administration Reauthorization and Amendment Act of 1988, the recipient is encouraged to utilize small businesses located in rural areas to the maximum extent possible. The recipient agrees to follow the six affirmative steps stated in 40 CFR 33.44(b), 31.36, or 35.6580 as appropriate. (3) Pursuant to Environmental Protection Agency Order 1000.25, dated January 24, 1990, the recipient agrees to use recycled paper for all reports which are prepared as a part of this Agreement and delivered to EPA. This requirement does not apply to reports which are prepared on forms supplied by EPA. This requirement applies even when the cost of recycled paper is higher than that of virgin paper. (4) The recipient agrees to ensure that all conference, meeting, convention, or training space funded in whole or in part with Federal funds, complies with The Hotel and Motel Fire Safety Act of 1990. (5) Pursuant to the Lobbying Disclosure Act of 1995, the recipient agrees to refrain from entering into any subagreement or contract under this Agreement with any organization described in Section 501(c)(4) of the Internal Revenue Code of 1986, unless such organization warrants that it does not, and will not, engage in lobbying activities prohibited by the Act as a special condition of the subagreement or contract. (6) The recipient agrees to provide the Cabinet with a copy of the recipient's current Title VI of the 1964 Civil Rights Act Plan. If the recipient does not have an existing plan, the recipient shall agree to use the Cabinet's current Title VI Plan. (7) By signing this contract, the recipient agrees to certify that all state taxes have been paid in accordance with Senate Bill 258 of the 1994 General Assembly (KRS Chapter 45A.485).

## V. CHOICE OF FORUM

Any legal action brought on the basis of this Agreement shall be filed in the Franklin County Circuit Court of the Commonwealth of Kentucky.

## VI. TERM OF CONTRACT

This Agreement is entered into and effective for the period beginning July 1, 1998 and ending on June 31, 2001. This Agreement may be further extended by written agreement of the parties hereto for an additional period.

## VII. CANCELLATION CLAUSE

Either party shall have the right to terminate and cancel this Agreement for cause at any time or upon thirty (30) days written notice to the other party.

## VIII. AMENDMENTS

This Agreement shall not be modified except by written agreement of both parties.

## IX. MISCELLANEOUS

The parties certify, by the signatures of duly authorized representatives hereinafter affixed, that they are legally entitled to enter into this Agreement, and that they shall not be violating, either directly or indirectly, any conflict of interest statute of the Commonwealth of Kentucky by performance of this Agreement. Further, the parties covenant that they presently have no conflict of interest, in any manner or degree, with the performance of services required to be performed under this Agreement. The parties further covenant that in the performance of this Agreement no persons having any such conflict of interest shall be employed. The signatures below signify acceptance and approval of this AGREEMENT.

Memorandum of Agreement, Natural Resources and Environmental Protection Cabinet and the University of Kentucky Research Foundation for the Kentucky Geological Survey.

**UNIVERSITY OF KENTUCKY**

**RECOMMENDED FOR APPROVAL:**

| | |
|---|---|
| ____________________________ | |
| Director, Kentucky Geological Survey | Date |

**APPROVED:**

| | |
|---|---|
| ____________________________ | |
| Director, University of Kentucky Research Foundation | Date |

**NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION CABINET**

**RECOMMENDED FOR APPROVAL:**

| | |
|---|---|
| ____________________________ | |
| Director, Division of Water | Date |
| ____________________________ | |
| Commissioner, Department for Environmental Protection | Date |
| ____________________________ | |
| Director, Division of Administrative Services | Date |

Memorandum of Agreement, Natural Resources and Environmental Protection Cabinet and the University of Kentucky Research Foundation for the Kentucky Geological Survey.

**EXAMINED AS TO LEGALITY AND FORM:**

_____________________________

General Counsel, Office of Legal Services — Date

**APPROVED:**

_____________________________

Secretary, Natural Resources and Environmental Protection Cabinet — Date

**FINANCE AND ADMINISTRATION CABINET**

**EXAMINED AS TO LEGALITY AND FORM:**

_____________________________

Attorney, Finance and Administration Cabinet — Date

**RECOMMENDED FOR APPROVAL:**

_____________________________

Commissioner, Department for Administration — Date

**APPROVED:**

_____________________________

Secretary, Finance and Administration Cabinet — Date

**ATTACHMENT I**
**KENTUCKY GEOLOGICAL SURVEY**
Computer and Laboratory Services Section

Analysis Parameters

| **INORGANIC-NONMETAL** | Method | Cost |
|---|---|---|
| Alkalinity | EPA 310.1 | |
| Chloride | EPA 300.0 (IC) | |
| Conductance | EPA 120.1 | |
| Fluoride | EPA 340.2 | |
| pH | EPA 150.1 | |
| Sulfate | EPA 300.0 (IC) | |
| | | $30.00 |
| **NUTRIENT** | | |
| Ammonia-Nitrogen | EPA 350.3 | |
| Kjeldahl-Nitrogen | EPA 351.4 | |
| Nitrate-Nitrogen | EPA 300.0 (IC) | |
| Nitrite-Nitrogen | EPA 354.1 | |
| Orthophosphate | EPA 365.3 | |
| | | $37.00 |
| **RESIDUE** | | |
| Suspended Solids | EPA 160.2 | |
| Dissolved Solids | EPA 160.1 | |
| | | $14.00 |
| **DEMAND** | | |
| CBOD | EPA 405.1 | |
| | | $14.00 |

**ORGANIC** EPA 507-508 (GC-ECD)

| Herbicide | Insecticide |
|---|---|
| Butylate | Malathion |
| Trifluralin | Chlorpyrifos |
| Atrazine | Endosulfan |
| Alachlor | Permethrin |
| Linuron | Diazinon |
| Metolachlor | |
| Pendimethalin | Fungicide |
| Simazine | Chorothalonil |

$67.00

**ATTACHMENT I** (Continued)

**INORGANIC METALS** EPA 200.7a (ICP)

| | |
|---|---|
| Aluminum | Magnesium |
| Antimony | Manganese |
| Arsenic | Nickel |
| Barium | Phosphorous |
| Beryllium | Potassium |
| Boron | Selenium |
| Cadmium | Silicon |
| Calcium | Silver |
| Chromium | Sodium |
| Cobalt | Strontium |
| Copper | Sulfur |
| Gold | Thallium |
| Iron | Tin |
| Lead | Vanadium |
| Lithium | Zinc |

$36.00

EPA 200.9 GFAA Methods

Arsenic
Chromium
Lead

$36.00

**TOTAL ANALYTICAL: $234.00**

## BUDGET

Budget Summary:

| Budget Categories | Project Activity Categories | | | | | | |
|---|---|---|---|---|---|---|---|
| | BMP Imple-mentation | Project Management | Public Education | Monitoring | Technical Assistance | Other | Total |
| **Personnel** | | | | | | | |
| **Supplies** | | | | | | | |
| **Equipment** | | | | | | | |
| **Travel** | | | | | | | |
| **Contractual** | | | | $49,504 | | | $49,504 |
| **Operating Costs** | | | | | | | |
| **Other** | | | | | | | |
| **TOTAL** | | | | $49,504 | | | $49,504 |

Detailed Budget:

| Budget Categories | Section 319(h) | Non-Federal Match | Total |
|---|---|---|---|
| **Personnel** | | | |
| **Supplies** | | | |
| **Equipment** | | | |
| **Travel** | | | |
| **Contractual** | $49,504 | | $49,504 |
| **Operating Costs** | | | |
| **Other** | | | |
| **TOTAL** | $49,504 | | $49,504 |
| | 100% | | 100% |

Budget Narrative

The total project budget is $49,504. This ($49,504) includes contractual sample analysis costs through a MOA with the Kentucky Geological Survey laboratory.

# APPENDIX B: QA/QC FOR WATER MONITORING

TITLE SECTION

Project Name

"IDENTIFICATION AND PRIORITIZATION OF KARST GROUNDWATER BASINS IN KENTUCKY FOR TARGETING RESOURCES FOR NONPOINT SOURCE POLLUTION PREVENTION AND ABATEMENT"

**B. QA/QC Plan Preparers**


David P. Leo, Geologist Supervisor – Registered

Kentucky Division of Water, Groundwater Branch
14 Reilly Road
Frankfort, Kentucky 40601

(502) 564-3410


Date

August 9, 1996

Project Description

This project is intended to identify karst groundwater basins in selected areas of the Mississippian Plateau physiographic province of west-central and south-west Kentucky that have potential or demonstrated nonpoint source pollution problems. Once identified, these basins will be prioritized based on the presence of, and the susceptibility to, nonpoint source pollution, land use within the basin and related threats posed by land use, use of the water in the basin, and the need for or application of best management practices within the basin. This priority scheme will help to appropriately target future nonpoint source resource, such as BMP implementation and modification, public education, and technical assistance at karst groundwater basins that have been established to have the most critical need.

Anticipated nonpoint source pollutants include: pesticides, primarily from agricultural use, secondarily from urban uses; and bacterial and nutrients from agriculture and onsite sewage disposal.

## <u>2.</u> <u>WATERBODY INFORMATION</u>

### <u>A.</u> 1. Stream Names

Determining which of the lower order karst groundwater basins (spring basins) to be studied is part of the proposed study. All of the karst groundwater basins to be studied will be in the basins of one of the following streams:

Ohio River
Sinking Creek
Rough River
Little River
Sinking Fork
Lower Cumberland River

### 2. Major River Basin

Ohio River
Lower Cumberland River

### 3. Water Body Number

To our knowledge, water body numbers have not been assigned to any of Kentucky's karst groundwater basins. However, every karst groundwater basin will be a tributary to one of the following streams:

Ohio River
Sinking Creek
Rough River
Little River
Sinking Fork
Lower Cumberland River

### 4. USGS Hydrologic Unit Number

U.S.G.S. Hydrologic Unit numbers have not been assigned to the karst groundwater basins that are to be delineated, assessed, and ranked. Additionally, individual basins to be delineated have not yet been identified as that is part of the function of the study. However, every karst groundwater basin will be a tributary to one of the following streams:

Ohio River
Sinking Creek
Rough River
Little River
Sinking Fork
Lower Cumberland River

5. **Stream Order**

Individual basins to be delineated have not yet been identified as that is part of the function of the study. Steam orders for these basins have traditionally not been assigned. Rather, tracer testing and unit base-flow measurements are used to approximate the size of karst groundwater basins. The areas of recharge for karst groundwater basins in the Pennyroyal of Kentucky correspond to surface stream watershed areas up to fourth-order streams. Every karst groundwater basin will be a tributary to one of the following streams:

Ohio River
Sinking Creek
Rough River
Little River
Sinking Fork
Lower Cumberland River

6. **Counties in Which Study Area is Located**

Breckinridge, Christian, Hardin, Meade, Todd, and Trigg.

7. **USGS 7.5-minute Topographic Quadrangles Containing Project Area**

**Northeast Study Area –** New Amsterdam, Mauckport, Lodiburg, Irvington, Guston, Rock Haven, Hardinsburg, Garfield, Big Spring, Kingswood, Custer, and Constantine

**Southwest Study Area –** Cobb, Gracey, Cadiz, Caledonia, Church Hill, Johnson Hollow, Roaring Spring, Herndon, Oak Grove, Trenton, Guthrie, and Allensville.

## 3. Monitoring Schedule

Initial monitoring will be conducted along with spring surveys and spring discharge measurements. Monitoring of each spring will continue throughout the study on a quarterly, or an as-needed basis. For example, springs that demonstrate highly variable water quality or that have a significant level of pollution may be monitored more frequently than non-impacted springs or spring with consistent water quality.

## 4. Monitoring Objectives

Gage base-flow discharge of selected springs;

Estimate groundwater recharge areas;

Evaluate land use within each delineated karst groundwater basin;

Determine actual or potential impacts of nonpoint source pollution to selected springs.

## 5. Study Area Description

The Mississippian Plateau physiographic province of Kentucky extends from the Jackson purchase Region on the west, south of the Western Coal Field, southwest of the Bluegrass Region, with the Eastern Coal Field serving as a boundary on the East. Three northern extensions, one between the Jackson Purchase and the Western Coal Field, one between the Bluegrass Region and the Western Coal Field and one between the Bluegrass Region and the Eastern Kentucky Coal Field extend north to the Ohio River.

A. Most of the karst basins that will be studied are located in rural settings, with only a few proximal to the urban center of Hopkinsville. Several areas within this province will be studied in this project, with the concentration of the work being done in the NE and SW study areas shown on figure 1.

B. A general description is offered which is applicable to most of the Mississippian Plateau. Site-specific information is not available as sites have not yet been identified per the nature of the study. The topography is generally gently rolling plains and flat regions containing dolines, karst windows, sinking streams, springs, and other karst features. Soils are predominantly clay or clayey loam soils with minor sandy loam soils. The geology dominantly consist of massively bedded carbonates of mid-Mississippian age. These carbonates are predominated by limestones with minor, but important, interbeds of calcareous shales, dolomites and cherts. These carbonates are locally capped by quartzitic sandstones. The study will be conducted in the Mississippian Plateau physiographic region. The ecoregion as applies to the Mississippian Plateau in Kentucky.

C. 1. Watershed acreages are to be approximated as part of the study using unit base-flow methods and further delineation will be conducted using traditional groundwater tracing techniques.

2. This study will be evaluating karst groundwater basins with recharge areas equilivent to 1$^{st}$-order through fourth-order streams. Flow patterns within these karst groundwater basins are dominated by conduit flow, but contain elements of diffuse flow and fracture flow. Karst topographic features that occur within the study area are dolines, sinking streams, springs, karst windows, along with other less common karst features. This project is designed to estimate and delineate numerous karst groundwater systems. All the systems being delineated and assessed are dominated by karst groundwater drainage systems.

D. Land use in this region varies widely from relatively undisturbed land to areas of urbanization. Most of the rural land is dedicated to agriculture and is used for row cropping of corn, soy beans, tobacco, oats, and wheat. Both dairy and beef cattle are raised in this region, and the area includes both hog farms and poultry farms. Sewage treatment varies from a predomination of rural on-site waste disposal systems (approved methods and otherwise) to urban sewer districts, as well as smaller package-plant facilities. Local quarrying of limestone occurs throughout the area, and historical niter mining has occurred in some areas. Numerous landfills, both permitted and non-permitted, occur through the Mississippian Plateau. Many major industries occur in the area, including automobile parts manufacturing, and others. The area is largely rural and this study is targeted to focus on agricultural nonpoint sources of pollution.

E. Site-specific maps are not available due to the nature of the study. A general regional map is presented to indicate areas where new karst groundwater basin delineations and assessments are planned, as well as areas where substantial historical data exists. The areas will be used to collect information sufficient to prioritize individual karst basins for further nonpoint source efforts and resource expenditures.

F. The project monitoring areas have not yet been identified to site-specific locations. It is an aspect of this project to provide geographic and land-use features as a part of the study.

## 6. Project Organization and Responsibility

The supervisor of the Technical Services Section of the Kentucky Division of Water's Groundwater Branch will coordinate this project. Individual staff members will be selected based on staff work loads at the time of the project. The laboratory analyses will be conducted by the Kentucky Geological Survey (KGS) laboratory. All data generated will be stored in the Kentucky Department for Environmental Protection's consolidated Groundwater Database and will be forwarded electronically to the Kentucky Geological Survey's Groundwater Data Repository.

## 7. Monitoring Program/Technical Design

A. Monitoring strategies include obtaining samples from springs during field reconnaissance and spring flow gaging. Thereafter, springs will be monitored on a quarterly basis as an attempt to assess seasonal/temporal variations in water quality parameters. Springs that demonstrate highly variable water quality may be sampled more frequently to determine the nature of the variation. Additionally, storm event sampling may be attempted at some locations with an automated sampler to determine variation due to storm events.

B. All monitoring station locations are to determined as part of the study, unless they are otherwise specifically identified in another study. All monitoring sites will be karst groundwater basin springs.

C. Refer to Table I – Sample Parameters and Methods, and to Table II – Sample Parameters, Containerization, Preservation and Holding Times.

Table II outlines the constituents that will be sampled as the monitoring/assessment effort of this study. Consistent with other monitoring efforts samples will be collected at each spring and samples analyzed for bulk parameters, nutrients, chemical and biological demand, pesticides, including most commonly used herbicides, insecticides, and fungicide. Samples may be analyzed for the major metals as part of an ongoing ambient monitoring program. Metals analyses will not be funded by this 310(h) project. See Table below for individual analytical methods used for each parameter.

Analysis of all samples are conducted by a contract lab according to methods approved by the Division of Environmental Services.

**TABLE I. SAMPLE PARAMETERS AND METHODS**

| PARAMETER | EPA WATER METHOD |
|---|---|
| Alkalinity | 310 |
| Fluoride | 340 |
| Chloride | 300 |
| Nitrite | 354.1 |
| Nitrate | 300 |
| TDS | 160.1 |
| TSS | 160.2 |
| Sulfate | 300 |
| Conductance | 120.1 |
| Orthophosphate | 365.2 |
| BOD | 405.1 |
| Pesticides | 507-508 |
| NH3 | 350 |
| TKN | 351 |
| Metals | 200 Series/200.7 |

D. Refer to Table II. Samples are taken as grab samples using properly decontaminated sampling devices and containers.

E. Sampling will begin with initial spring base-flow gaging and will be conducted quarterly for two years. More frequent sampling may occur if the water quality of a spring varies greatly from one sampling event to the next. Storm event sampling will be conducted on some springs, if possible, to determine the effective variations in spring water quality related to rain events. Storm-event sampling will proceed through the entire event if possible. Automatic sampling will not be conducted in such a manner as to exceed the methods holding time for any parameter being sampled.

## 8. Chain-of-Custody Procedures

A. Sample containers will be labeled with the site name and well or spring identification number, sample collection date and time, analysis requested, preservation method, and collector's initials. Sampling personnel will complete a Chain-of-Custody Record, developed in conjunction with the KGS laboratory, for each sample. The KGS laboratory will be responsible for following approved laboratory QA/QC procedures, conducting analyses within the designated holding times, following EPA-approved analytical techniques, and reporting analytical results to the Groundwater Branch.

B. Name: David P. Leo
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Agency: Groundwater Branch
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## 9. Quality Assurance/Quality Control Procedures

A. Field Reconnaissance

Field Reconnaissance will be conducted prior to groundwater sampling to assess the suitability and accessibility of each site. A Spring Inventory Record will be completed for each spring gaged. Site locations will be plotted on 7.5-minute topographic maps, and identified by a site name and unique identification number (AKGWA number) for incorporation into the Department for Environmental Protection's Consolidated Groundwater Data Base and the Kentucky Geological Survey's Groundwater Data Repository.

1. Decontamination Protocols

All sampling supplies that come in contact with the sample will be new, disposable equipment, or will be decontaminated prior to and after each use, using the following protocols.

Sample Collection and Filtration Equipment

Sample collection equipment such as bailers and buckets will consist of Teflon. Disposable bailers are preferable. Any reusable equipment will be decontaminated by rinsing with a 10% hydrochloric acid (HCL) solution, triple rinsed with deionized water, and triple rinsed with water from the source to be sampled prior to collecting a sample. After sampling is complete, excess sample will be disposed of, and the equipment will again be rinsed with the 10% HCL solution and triple rinsed with deionized water. If oily substances or films are encountered during sampling a pesticide grade acetone or xylene rinse will be used as the first rinse of the decontamination procedure on reusable sampling equipment.

New 0.45 micron filters will be used at each sampling site. Any tubing that contacts the sample will also be new. Any reusable filter apparatus will be decontaminated in the same manner as sample collection equipment. Additionally, any intermediary collection vessel will be triple rinsed with filtrate prior to use.

Field Meters

Field meter probes will be rinsed with deionized water prior to and after each use.

2. Equipment Calibration

Field meters will be calibrated in accordance with the manufacturer's specifications, using standard buffer solutions or zero adjust (for flow meters). Meter probes will be decontaminated according to the manufacture's decontamination protocols for field meters and stored according to the manufacture's recommendations.

3. Sample Collection and Preservation/Contamination Prevention

Water samples will be fresh groundwater collected prior to any type of water treatment. Samples not requiring field filtration will be collected directly in the sampling container. Samples requiring field filtration will be collected in a disposable cubitainer or Teflon bucket decontaminated in accordance with decontamination protocols for sample collection and filtration equipment, filtered, and transferred to the appropriate container.

Sample containers will be obtained from the Kentucky Division of Environmental Services, and will be new or laboratory-decontaminated in accordance with Division of Environmental Services accepted procedures. Sample containerization, preservation, and holding time requirements are presented in Table II. Necessary preservatives will be added in the field; preservatives for dissolved constituents will be added after field filtration. Samples will be stored in coolers packed with ice for transport to the contract laboratory.

Sample containers will be labeled with the site name and identification number, sample collection date and time, analysis requested, preservation method, and collector's initials. Sampling personnel will complete a Chain-of-Custody Record (form DEP 5005A or equivalent) for each sample. The contract laboratory will be responsible for following approved laboratory QA/QC procedures, conducting analyses within the designated holding times, following EPA-approved analytical techniques, and reporting analytical results to the Groundwater Branch.

Samples will be collected as near to the spring resurgence as possible. If inhospitable terrain prohibits spring access, a decontaminated Teflon bucket attached to a new polypropylene rope may be lowered to the spring to collect the sample.

4. Field Measurements

Conductivity, temperature, and pH will be measured in the field at each site using portable automatic temperature compensating meters, and recorded in a field log book. Dissolved oxygen and Eh meter readings may be taken at problem spring sites to help better define the water chemistry. Meters will be calibrated according to the manufacturer's specifications, using standard buffer solutions. Meter probes will be decontaminated according to decontamination protocols for field meters and stored according to the manufacturer's recommendations.

Flow meter measurements will follow the manufactures recommendations as well as USGS protocols for stream flow measurements to ensure consistent and accurate flow measurements in the field.

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**Table II. SAMPLE PARAMETER, CONTAINERIZATION, PRESERVATION AND HOLDING TIMES**

| Parameter | Container | Preservative | Holding Time |
|---|---|---|---|
| **Bulk Parameters**<br>Alkalinity<br>Chloride<br>Conductance<br>Fluoride<br>pH<br>Sulfate<br>Nitrate Nitrogen<br>Nitrite Nitrogen<br>Total Suspended Solids<br>Total Dissolved Solids | 1000 ml plastic | Cool to $4^oC$ | 14 days<br>28 days<br>28 days<br>28 days<br>2 hours<br>28 days<br>48 hours<br>48 hours<br>7 days<br>7 days |
| **Nutrients**<br>Ammonia-Nitrogen<br>Total Kjeldahl-Nitrogen | 1000 ml plastic | $H_2SO_4$ to pH <2<br>Cool to $4^oC$ | 28 days |
| Orthophosphate | 1000 ml plastic | Cool to $4^oC$ | 48 hours |
| **Pesticides**<br>Herbicides: Alachlor, Atrazine, Butylate, Cyanazine, Linuron, Metolachlor, Pendimethalin, Simazine, Trilfluralin<br>Insecticides: Chlorpyrifos, Diazinon, Endosulfan, Malathion, Permethrin, Acetochlor<br>Fungicides: Chlorothalonil | 950 ml glass | Cool to $4^oC$ | 7 days prior to extraction.<br>40 days after extraction. |
| **Metals**<br>Aluminum, Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Gold, Iron, Lead, Lithium, Magnesium, Manganese, Nickel, Sodium, Phosphorus, Potassium, Selenium, Silicon, Silver, Strontium, Sulfur, Thallium, Tin, Vanadium, Zinc | 1000 ml plastic | Filter on site<br>$HNO_3$ to pH <2<br>Cool to $4^oC$ | 6 months |

# Appendix C: SUMMARY OF WATER QUALITY ANALYSES

| | PARAMETER | WATER QUALITY STANDARD | TOTAL NUMBER OF SAMPLES | SAMPLES < 6.5 | SAMPLES 6.5 - 8.5 | SAMPLES > 8.5 |
|---|---|---|---|---|---|---|
| GENERAL PARAMETERS | pH | 6.5 - 8.5 pH units [2] | 96 | 0 | 96 | 0 |

| | PARAMETER | WATER QUALITY STANDARD | TOTAL NUMBER OF SAMPLES | SAMPLES < MDL | SAMPLES W/DETECTS | DETECTS > STANDARD | DETECTS > 1/2 STANDARD |
|---|---|---|---|---|---|---|---|
| GENERAL PARAMETERS | TOC | - | 96 | 28 | 68 | - | - |
| INORGANICS | Chloride | 250 mg/L [2] | 96 | 0 | 96 | 0 | 0 |
| | Sulfate | 250 mg/L [2] | 96 | 1 | 95 | 0 | 0 |
| NUTRIENTS | Ammonia-N | 0.110 mg/L [4] | 96 | 86 | 10 | 0 | 2 |
| | Nitrate-N | 10 mg/L [1] | 96 | 0 | 96 | 0 | 23 |
| | Nitrite-N | 1 mg/L [1] | 96 | 5 | 91 | 0 | 0 |
| | Orthophosphate-P | 0.04 mg/L [7] | 96 | 1 | 95 | 44 | 80 |
| | Total Phosphorus | 0.1 mg/L [6] | 96 | 43 | 53 | 4 | 17 |
| PESTICIDES | Alachlor | 0.002 mg/L [1] | 95 | 94 | 1 | 0 | 0 |
| | Atrazine | 0.003 mg/L [1] | 95 | 71 | 24 | 8 | 11 |
| | ***Atrazine*** | ***0.00067 mg/L [4]*** | ***95*** | ***71*** | ***24*** | ***20*** | ***24*** |
| | Metolachlor | 0.1 mg/L [3] | 95 | 87 | 8 | 0 | 0 |
| | Simazine | 0.004 mg/L [1] | 95 | 84 | 11 | 0 | 0 |
| RESIDUES | TDS | 500 mg/L [2] | 96 | 5 | 91 | 0 | 33 |
| | TSS | 35 mg/L [5] | 96 | 54 | 42 | 3 | 8 |

* Pesticides sample for Buttermilk Falls on 4/26/00 was destroyed.

Standards:
[1] MCL (Maximum Contaminant Level)
[2] SMCL (Secondary Maximum Contaminant Level)
[3] HAL (Health Advisory Level)
[4] DEP (Kentucky Department for Environmental Protection risk-based number)
[5] KPDES (Kentucky Pollutant Discharge Elimination System)
[6] NAWQA (National Water-Quality Assessment Program (USGS))
[7] TXSW (Texas Surface Water Standard)

**Summary Statistics - pH**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 7.44 | 7.70 | 8.08 | 0.286 |
| FRENCH CREEK | #1838 | 8 | 7.39 | 7.63 | 8.13 | 0.242 |
| BUTTERMILK FALLS | #1824 | 8 | 7.77 | 7.92 | 8.32 | 0.447 |
| HEAD OF WOLF CR. | #1063 | 8 | 7.59 | 7.68 | 8.06 | 0.140 |
| BARKERS MILL | #0859 | 8 | 6.92 | 7.31 | 7.85 | 0.580 |
| RIVER BEND | #0860 | 8 | 7.12 | 7.27 | 7.72 | 0.302 |
| COOK'S | #1141 | 8 | 7.23 | 7.36 | 7.98 | 0.391 |
| BRELSFORD | #1448 | 8 | 6.95 | 7.38 | 7.63 | 0.395 |
| MILL STREAM | #0203 | 8 | 7.08 | 7.48 | 8.14 | 0.603 |
| KING | #1489 | 8 | 6.76 | 7.31 | 7.82 | 0.390 |
| WALTON | #1457 | 8 | 6.87 | 7.34 | 7.94 | 0.445 |
| WRIGHT | #1475 | 8 | 7.28 | 7.57 | 8.06 | 0.365 |
| Total | | 96 | 6.76 | 7.58 | 8.32 | 0.486 |
| Total NE Springs | | 32 | 7.39 | 7.76 | 8.32 | 0.300 |
| Total SW Springs | | 64 | 6.76 | 7.35 | 8.14 | 0.380 |

**Summary Statistics – TOC**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 0.8 | 1.185 | 22.8 | 1.15 |
| FRENCH CREEK | #1838 | 8 | 0.9 | 1.4 | 2.8 | 1.27 |
| BUTTERMILK FALLS | #1824 | 8 | < 0.5 | 0.65 | 1.3 | 0.345 |
| HEAD OF WOLF CR. | #1063 | 8 | 1.4 | 2.95 | 4.44 | 1.75 |
| BARKERS MILL | #0859 | 8 | < 0.5 | < 0.5 | 0.9 | 0 |
| RIVER BEND | #0860 | 8 | < 0.5 | < 0.5 | 2.1 | 0.435 |
| COOK'S | #1141 | 8 | < 0.5 | 0.6 | 2.1 | 1.02 |
| BRELSFORD | #1448 | 8 | < 0.5 | < 0.5 | 1.3 | 0.415 |
| MILL STREAM | #0203 | 8 | 0.8 | 1.5 | 4.8 | 1.27 |
| KING | #1489 | 8 | < 0.5 | < 0.5 | 2.4 | 1.28 |
| WALTON | #1457 | 8 | < 0.5 | 0.6 | 3.2 | 1.87 |
| WRIGHT | #1475 | 8 | 0.9 | 1.4 | 2.4 | 0.465 |
| Total | | 96 | < 0.5 | 0.9 | 22.8 | 1.215 |
| Total NE Springs | | 32 | < 0.5 | 1.335 | 22.8 | 1.7 |
| Total SW Springs | | 64 | < 0.5 | 0.665 | 4.8 | 1.05 |

**Summary Statistics - Chloride**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 3.8 | 7.1 | 16.8 | 2.2 |
| FRENCH CREEK | #1838 | 8 | 4.6 | 8.6 | 10.2 | 2.6 |
| BUTTERMILK FALLS | #1824 | 8 | 4.7 | 7.8 | 10.9 | 2.2 |
| HEAD OF WOLF CR. | #1063 | 8 | 2.4 | 3.9 | 6.0 | 1.9 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | 5.5 | 7.1 | 8.3 | 2.2 |
| RIVER BEND | #0860 | 8 | 6.4 | 7.2 | 8.6 | 0.8 |
| COOK'S | #1141 | 8 | 6.0 | 8.7 | 11.0 | 2.4 |
| BRELSFORD | #1448 | 8 | 4.4 | 5.3 | 5.7 | 0.7 |
| MILL STREAM | #0203 | 8 | 6.7 | 9.4 | 11.8 | 2.5 |
| KING | #1489 | 8 | 4.8 | 5.5 | 7.2 | 1.4 |
| WALTON | #1457 | 8 | 4.1 | 5.4 | 6.4 | 1.3 |
| WRIGHT | #1475 | 8 | 7.8 | 9.5 | 11.2 | 2.1 |
| | | | | | | |
| Total | | 96 | 2.4 | 7.1 | 16.8 | 3.1 |
| NE Total Springs | | 32 | 2.4 | 7.0 | 16.8 | 3.7 |
| SW Total Springs | | 64 | 4.1 | 7.1 | 11.8 | 2.9 |

**Summary Statistics - Sulfate**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 17.8 | 37.8 | 104 | 36.3 |
| FRENCH CREEK | #1838 | 8 | 13.2 | 20.05 | 26.3 | 4.05 |
| BUTTERMILK FALLS | #1824 | 8 | 12.9 | 16.25 | 25.7 | 2.3 |
| HEAD OF WOLF CR. | #1063 | 8 | 15 | 21.6 | 33.4 | 6.15 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | < 5 | 5.65 | 6.3 | 0.6 |
| RIVER BEND | #0860 | 8 | 5.2 | 5.75 | 7.2 | 0.65 |
| COOK'S | #1141 | 8 | 7.2 | 8.4 | 10.1 | 1.8 |
| BRELSFORD | #1448 | 8 | 6 | 6.85 | 8.2 | 1.3 |
| MILL STREAM | #0203 | 8 | 9.1 | 11.6 | 17.4 | 4.8 |
| KING | #1489 | 8 | 5.2 | 5.95 | 7.3 | 0.9 |
| WALTON | #1457 | 8 | 5.7 | 6.8 | 7.9 | 1.05 |
| WRIGHT | #1475 | 8 | 6.2 | 6.75 | 9.6 | 1.5 |
| | | | | | | |
| Total | | 96 | < 5 | 8 | 104 | 10.45 |
| NE Total Springs | | 32 | 12.9 | 20.3 | 104 | 9.75 |
| SW Total Springs | | 64 | < 5 | 6.7 | 17.4 | 2.05 |

**Summary Statistics - Ammonia ($NH_3$-N)**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| FRENCH CREEK | #1838 | 8 | < 0.02 | < 0.02 | 0.05 | 0.005 |
| BUTTERMILK FALLS | #1824 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| BARKERS MILL | #0859 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| RIVER BEND | #0860 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| COOK'S | #1141 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| BRELSFORD | #1448 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| MILL STREAM | #0203 | 8 | < 0.02 | < 0.02 | 0.1 | 0.015 |
| KING | #1489 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| WALTON | #1457 | 8 | < 0.02 | < 0.02 | < 0.02 | 0 |
| WRIGHT | #1475 | 8 | < 0.02 | 0.03 | 0.06 | 0.02318 |
| Total | | 96 | < 0.02 | < 0.02 | 0.1 | 0 |
| NE Total Springs | | 32 | < 0.02 | < 0.02 | 0.05 | 0 |
| SW Total Springs | | 64 | < 0.02 | < 0.02 | 0.1 | 0 |

**Summary Statistics - Nitrate ($NO_3$-N)**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 1.2 | 2.08 | 3.03 | 0.86 |
| FRENCH CREEK | #1838 | 8 | 2.49 | 2.69 | 3.59 | 0.425 |
| BUTTERMILK FALLS | #1824 | 8 | 1.7 | 1.83 | 2.21 | 0.245 |
| HEAD OF WOLF CR. | #1063 | 8 | 0.588 | 0.767 | 1.04 | 0.202 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | 4.54 | 5.315 | 6.19 | 0.59 |
| RIVER BEND | #0860 | 8 | 5.24 | 5.685 | 6.85 | 0.77 |
| COOK'S | #1141 | 8 | 3.32 | 4 | 5.49 | 1.02 |
| BRELSFORD | #1448 | 8 | 1.15 | 1.82 | 2.64 | 1.04 |
| MILL STREAM | #0203 | 8 | 3.46 | 4.43 | 6.73 | 2.44 |
| KING | #1489 | 8 | 3.46 | 4.025 | 4.81 | 1.07 |
| WALTON | #1457 | 8 | 3.23 | 3.865 | 6.24 | 1.085 |
| WRIGHT | #1475 | 8 | 3.1 | 4.825 | 7.05 | 2.41 |
| | | | | | | |
| Total | | 96 | 0.588 | 3.63 | 7.05 | 2.835 |
| | | | | | | |
| NE Total Springs | | 32 | 0.588 | 1.93 | 3.59 | 1.4 |
| | | | | | | |
| SW Total Springs | | 64 | 1.15 | 4.6 | 7.05 | 1.84 |

**Summary Statistics - Nitrite ($NO_2$-N)**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 0.001 | 0.0025 | 0.008 | 0.003 |
| FRENCH CREEK | #1838 | 8 | 0.002 | 0.005 | 0.01 | 0.005 |
| BUTTERMILK FALLS | #1824 | 8 | < 0.001 | 0.002 | 0.009 | 0.004 |
| HEAD OF WOLF CR. | #1063 | 8 | 0.002 | 0.0045 | 0.007 | 0.0045 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | 0.001 | 0.0025 | 0.011 | 0.0025 |
| RIVER BEND | #0860 | 8 | 0.001 | 0.0035 | 0.012 | 0.0015 |
| COOK'S | #1141 | 8 | < 0.001 | 0.0035 | 0.007 | 0.0035 |
| BRELSFORD | #1448 | 8 | < 0.001 | 0.0025 | 0.007 | 0.0025 |
| MILL STREAM | #0203 | 8 | 0.004 | 0.008 | 0.025 | 0.0075 |
| KING | #1489 | 8 | < 0.001 | 0.002 | 0.007 | 0.004 |
| WALTON | #1457 | 8 | < 0.001 | 0.0045 | 0.009 | 0.005 |
| WRIGHT | #1475 | 8 | 0.009 | 0.0205 | 0.047 | 0.0245 |
| | | | | | | |
| Total | | 96 | < 0.001 | 0.004 | 0.047 | 0.005 |
| | | | | | | |
| NE Total Springs | | 32 | < 0.001 | 0.003 | 0.01 | 0.0045 |
| | | | | | | |
| SW Total Springs | | 64 | < 0.001 | 0.004 | 0.047 | 0.006 |

**Summary Statistics - Orthophosphate ($PO_4$-P)**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 0.013 | 0.0575 | 0.082 | 0.042 |
| FRENCH CREEK | #1838 | 8 | 0.01 | 0.0755 | 0.103 | 0.0515 |
| BUTTERMILK FALLS | #1824 | 8 | 0.007 | 0.0185 | 0.041 | 0.0255 |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.003 | 0.029 | 0.047 | 0.0335 |
| BARKERS MILL | #0859 | 8 | 0.023 | 0.0435 | 0.064 | 0.023 |
| RIVER BEND | #0860 | 8 | 0.033 | 0.0395 | 0.07 | 0.025 |
| COOK'S | #1141 | 8 | 0.033 | 0.043 | 0.075 | 0.024 |
| BRELSFORD | #1448 | 8 | 0.006 | 0.032 | 0.045 | 0.0245 |
| MILL STREAM | #0203 | 8 | 0.022 | 0.049 | 0.077 | 0.0245 |
| KING | #1489 | 8 | 0.028 | 0.0315 | 0.054 | 0.0145 |
| WALTON | #1457 | 8 | 0.016 | 0.043 | 0.078 | 0.0345 |
| WRIGHT | #1475 | 8 | 0.007 | 0.038 | 0.144 | 0.03 |
| Total | | 96 | < 0.003 | 0.0385 | 0.144 | 0.0265 |
| NE Total Springs | | 32 | < 0.003 | 0.0365 | 0.103 | 0.0465 |
| SW Total Springs | | 64 | 0.006 | 0.0395 | 0.144 | 0.023 |

**Summary Statistics - Total Phosphorus**

| Spring | | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 0.005 | < 0.054 | 0.117 | - |
| FRENCH CREEK | #1838 | 8 | 0.03 | 0.057 | 0.16 | - |
| BUTTERMILK FALLS | #1824 | 8 | < 0.006 | < 0.054 | < 0.054 | - |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.005 | < 0.054 | < 0.054 | - |
| BARKERS MILL | #0859 | 8 | < 0.006 | < 0.054 | 0.06 | - |
| RIVER BEND | #0860 | 8 | < 0.005 | < 0.054 | 0.099 | - |
| COOK'S | #1141 | 8 | < 0.006 | < 0.054 | 0.06 | - |
| BRELSFORD | #1448 | 8 | < 0.005 | < 0.054 | < 0.054 | - |
| MILL STREAM | #0203 | 8 | < 0.006 | < 0.054 | 0.06 | - |
| KING | #1489 | 8 | < 0.006 | < 0.054 | 0.13 | - |
| WALTON | #1457 | 8 | < 0.006 | < 0.054 | 0.06 | - |
| WRIGHT | #1475 | 8 | < 0.006 | < 0.054 | < 0.054 | - |
| Total | | 96 | < 0.005 | < 0.054 | 0.16 | - |
| NE Total Springs | | 32 | < 0.005 | < 0.054 | 0.16 | - |
| SW Total Springs | | 64 | < 0.005 | < 0.054 | 0.13 | - |

**Summary Statistics – Alachlor**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| FRENCH CREEK | #1838 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| BUTTERMILK FALLS | #1824 | 7 | < 0.00002 | < 0.00002 | 0.000046 | 0 |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| BARKERS MILL | #0859 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| RIVER BEND | #0860 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| COOK'S | #1141 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| BRELSFORD | #1448 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| MILL STREAM | #0203 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| KING | #1489 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| WALTON | #1457 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| WRIGHT | #1475 | 8 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |
| Total | | 95 | < 0.00002 | < 0.00002 | 0.000046 | 0 |
| NE Total Springs | | 31 | < 0.00002 | < 0.00002 | 0.000046 | 0 |
| SW Total Springs | | 64 | < 0.00002 | < 0.00002 | < 0.00002 | 0 |

**Summary Statistics - Atrazine**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 0.0003 | < 0.0003 | 0.000674 | 0.000124 |
| FRENCH CREEK | #1838 | 8 | < 0.0003 | < 0.0003 | 0.006746 | 0 |
| BUTTERMILK FALLS | #1824 | 7 | < 0.0003 | < 0.0003 | 0.003934 | 0.000901 |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.0003 | < 0.0003 | 0.002942 | 0 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | < 0.0003 | < 0.0003 | 0.00074 | 0 |
| RIVER BEND | #0860 | 8 | < 0.0003 | < 0.0003 | 0.003154 | 0.000519 |
| COOK'S | #1141 | 8 | < 0.0003 | < 0.0003 | 0.0062 | 0.0002645 |
| BRELSFORD | #1448 | 8 | < 0.0003 | < 0.0003 | 0.001448 | 0.0001425 |
| MILL STREAM | #0203 | 8 | < 0.0003 | < 0.0003 | 0.002993 | 0.001403 |
| KING | #1489 | 8 | < 0.0003 | < 0.0003 | 0.009929 | 0.0006355 |
| WALTON | #1457 | 8 | < 0.0003 | < 0.0003 | 0.011903 | 0.0016505 |
| WRIGHT | #1475 | 8 | < 0.0003 | < 0.0003 | 0.001146 | 0.0001455 |
| | | | | | | |
| Total | | 95 | < 0.0003 | < 0.0003 | 0.011903 | 0.000109 |
| | | | | | | |
| NE Total Springs | | 31 | < 0.0003 | < 0.0003 | 0.006746 | 0 |
| | | | | | | |
| SW Total Springs | | 64 | < 0.0003 | < 0.0003 | 0.011903 | 0.0002335 |

**Summary Statistics - Metolachlor**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 0.0002 | < 0.0002 | < 0.0002 | 0 |
| FRENCH CREEK | #1838 | 8 | < 0.0002 | < 0.0002 | < 0.0002 | 0 |
| BUTTERMILK FALLS | #1824 | 7 | < 0.0002 | < 0.0002 | < 0.0002 | 0 |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.0002 | < 0.0002 | 0.0002 | 0 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | < 0.0002 | < 0.0002 | < 0.0002 | 0 |
| RIVER BEND | #0860 | 8 | < 0.0002 | < 0.0002 | 0.000567 | 0 |
| COOK'S | #1141 | 8 | < 0.0002 | < 0.0002 | 0.00133 | 0 |
| BRELSFORD | #1448 | 8 | < 0.0002 | < 0.0002 | < 0.0002 | 0 |
| MILL STREAM | #0203 | 8 | < 0.0002 | < 0.0002 | 0.00055 | 0.0000685 |
| KING | #1489 | 8 | < 0.0002 | < 0.0002 | 0.000302 | 0 |
| WALTON | #1457 | 8 | < 0.0002 | < 0.0002 | 0.001901 | 0.0000245 |
| WRIGHT | #1475 | 8 | < 0.0002 | < 0.0002 | < 0.0002 | 0 |
| | | | | | | |
| Total | | 95 | < 0.0002 | < 0.0002 | 0.001901 | 0 |
| | | | | | | |
| NE Total Springs | | 31 | < 0.0002 | < 0.0002 | 0.0002 | 0 |
| | | | | | | |
| SW Total Springs | | 64 | < 0.0002 | < 0.0002 | 0.001901 | 0 |

**Summary Statistics - Simazine**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 0.0003 | < 0.0003 | < 0.0003 | 0 |
| FRENCH CREEK | #1838 | 8 | < 0.0003 | < 0.0003 | 0.001243 | 0 |
| BUTTERMILK FALLS | #1824 | 7 | < 0.0003 | < 0.0003 | 0.001311 | 0.000415 |
| HEAD OF WOLF CR. | #1063 | 8 | < 0.0003 | < 0.0003 | 0.00083 | 0 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | < 0.0003 | < 0.0003 | < 0.0003 | 0 |
| RIVER BEND | #0860 | 8 | < 0.0003 | < 0.0003 | 0.000487 | 0.000046 |
| COOK'S | #1141 | 8 | < 0.0003 | < 0.0003 | 0.000602 | 0 |
| BRELSFORD | #1448 | 8 | < 0.0003 | < 0.0003 | < 0.0003 | 0 |
| MILL STREAM | #0203 | 8 | < 0.0003 | < 0.0003 | 0.001579 | 0.0002075 |
| KING | #1489 | 8 | < 0.0003 | < 0.0003 | 0.000556 | 0 |
| WALTON | #1457 | 8 | < 0.0003 | < 0.0003 | < 0.0003 | 0 |
| WRIGHT | #1475 | 8 | < 0.0003 | < 0.0003 | 0.000561 | 0 |
| | | | | | | |
| Total | | 95 | < 0.0003 | < 0.0003 | 0.001579 | 0 |
| | | | | | | |
| NE Total Springs | | 31 | < 0.0003 | < 0.0003 | 0.001311 | 0 |
| | | | | | | |
| SW Total Springs | | 64 | < 0.0003 | < 0.0003 | 0.001579 | 0 |

**Summary Statistics - TDS**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | 196 | 290 | 462 | 113 |
| FRENCH CREEK | #1838 | 8 | 190 | 246 | 334 | 71 |
| BUTTERMILK FALLS | #1824 | 8 | < 10 | 253 | 358 | 96 |
| HEAD OF WOLF CR. | #1063 | 8 | 80 | 156 | 220 | 96 |
| | | | | | | |
| BARKERS MILL | #0859 | 8 | 160 | 235 | 294 | 34 |
| RIVER BEND | #0860 | 8 | 152 | 258 | 310 | 55 |
| COOK'S | #1141 | 8 | 220 | 244 | 302 | 37 |
| BRELSFORD | #1448 | 8 | < 10 | 125 | 224 | 162 |
| MILL STREAM | #0203 | 8 | < 10 | 252 | 344 | 125 |
| KING | #1489 | 8 | < 10 | 181 | 274 | 75 |
| WALTON | #1457 | 8 | 36 | 225 | 252 | 60 |
| WRIGHT | #1475 | 8 | 172 | 233 | 266 | 51 |
| | | | | | | |
| Total | | 96 | < 10 | 232 | 462 | 73 |
| NE Total Springs | | 32 | 10 | 235 | 462 | 110 |
| SW Total Springs | | 64 | < 10 | 226 | 344 | 74 |

**Summary Statistics - TSS**

| Spring | ID # | Count | Minimum | Median | Maximum | Interquartile Range |
|---|---|---|---|---|---|---|
| BOILING | #0855 | 8 | < 3 | 3.5 | 92 | 11 |
| FRENCH CREEK | #1838 | 8 | < 3 | 14 | 45 | 22.5 |
| BUTTERMILK FALLS | #1824 | 8 | < 3 | < 3 | 21 | 3 |
| HEAD OF WOLF CR. | #1063 | 8 | < 3 | < 3 | 20 | 5 |
| BARKERS MILL | #0859 | 8 | < 3 | 3.5 | 9 | 5.5 |
| RIVER BEND | #0860 | 8 | < 3 | 4.5 | 17 | 4 |
| COOK'S | #1141 | 8 | < 3 | 3.5 | 8 | 3 |
| BRELSFORD | #1448 | 8 | < 3 | < 3 | 13 | 1 |
| MILL STREAM | #0203 | 8 | < 3 | < 3 | 15 | 5 |
| KING | #1489 | 8 | < 3 | 3.5 | 55 | 9.5 |
| WALTON | #1457 | 8 | < 3 | < 3 | 4 | 0 |
| WRIGHT | #1475 | 8 | < 3 | < 3 | 20 | 11 |
| Total | | 96 | < 3 | < 3 | 92 | 4.5 |
| NE Total Springs | | 32 | < 3 | < 3 | 92 | 12.5 |
| SW Total Springs | | 64 | < 3 | < 3 | 55 | 3.5 |

# APPENDIX D: INDIVIDUAL DYE-TRACE RECORDS

**TRACER INJECTION SITE**

1. Name of Dye Trace (Site Location): ~~Kangy~~ Kanagy Sink, # 95 - 10 - JAR (Year – Trace # – Initials)
2. Date of Injection: 11 / 30 / 95 (Month / Day / Year) Time: 3:50 ( ) a.m. (✓) p.m.
3. Owner of Injection Site: Melvin Kangy Phone: ( )
4. Quadrangle/County: Guthrie / Todd
5. Elevation: 620' (✓) map ( ) measured 6. Latitude: Longitude:
7. Description of Injection Site:
   ( ) sinking stream (✓) sinkhole ( ) water well ( ) injection well
   ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other
   Remarks
8. Formation Receiving Tracer Injection: Ste. Genevieve LS.
9. Flow Conditions: (✓) low ( ) moderate ( ) high
10. Induced Flow? ( ) no (✓) yes 100 gal (Pre-injection) / 50 gal (Post-injection) 30 minutes (Elapsed Time)
11. Tracing Agent: Amt 3.0 lb ( ) Fluor. ( ) Rhod. WT ( ) OB (✓) DY96 ( ) other

**RECORD OF DYE TRACE**

Principal Investigator Joseph A. Ray Field Personnel Bill Stapleton

Precipitation before & during trace

| ID | Location of Dye Receptors | Background | Results | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Date | 11-20 | 11-30 | 12-6 | 12-13 | 12-19 | 12-27 | |
| | Duration | 4d | | | | | | |
| 1 | Guthrie Trib-TN | – | / | / | – | | | |
| 2 | Merriweather E | – | L | – | L | N | | |
| 4 | Spillway Sp. | – | – | – | – | – | | |
| 5 | Sadler Sp. | – | – | – Dry | D | – | | |
| 7 | Downer Sp. | Dry | D | D | D | D | | |
| 8 | Sp. Cr. @ Downer | – | – | – | – | – | | |
| 9 | Yodell Sp. | Dry | D | D | D | N | | |
| 10 | Sp. Cr. @ Lester | – | – | – | – | / | | |
| 14 | Sp. Cr. @ 181 | – | – | – | – | / | | |
| 20 | Franks BH | – | – | + | + | / | + | |
| 21 | Franks Stream | – | – | – | + | / | – | |
| 22 | Cain Sp. | – | – | – | – | / | | |
| 23 | Stooksbury Sp. | – | – | – | – | ? | | |
| 3 | Merriweather W | | N | L | L | N | | |
| 24 | Wright Sp. | | N | – | – | – | | |
| 25 | Short Run Sp. (Duck Sp) | | N | – | – | – | | |

go to 95-13-JAR

Legend:
+ Positive
++ Very Positive
+++ Extremely Positive
– Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed

Remarks TT = 3.7 Km in 139 hr = 27 M/hr. (Franks BH)

Interpretation

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):**__________ # 95-10-JAR (cont.)
   Year -- Trace # -- Initials
2. **Date of Injection:** _____ / _____ / _____ (Month / Day / Year) **Time:**_____ ( ) a.m. ( ) p.m.
3. **Owner of Injection Site:**__________ **Phone:** ( )__________
4. **Quadrangle/County:**__________ / __________
5. **Elevation:**_____ ( ) map ( ) measured 6. **Latitude:**_____ **Longitude:**_____
7. **Description of Injection Site:**
   - ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   - ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks__________
8. **Formation Receiving Tracer Injection:**__________
9. **Flow Conditions:** ( ) low ( ) moderate ( ) high
10. **Induced Flow?** ( ) no ( ) yes _____ / _____ (Pre-injection / Post-injection) _____ minutes (Elapsed Time)
11. **Tracing Agent:** Amt_____ ( ) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other_____

## RECORD OF DYE TRACE

**Principal Investigator**__________ **Field Personnel**__________
**Precipitation before & during trace**__________

| | Date | | 11-30 | 12-6 | 12-13 | 12-19 | 12-28 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| ID | Location of Dye Receptors | Back-ground | Results | | | | | | | | | | | | | |
| 26 | Culvert Sp (Gorby Sp) | | | N | – | – | | | | | | | | | | |
| 27 | Herman Win. | | N | – | – | / | – | R | | | | | | | | |
| 28 | Mouth of Merriwether Run | | N | – | – | – | | | | | | | | | | |
| 29 | Robertson Window | | | N | – | – | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
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go to 95-13-JAR

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks**__________
**Interpretation**__________

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. Name of Dye Trace (Site Location): Wright Swallet # 96 - 2 - JAR
   (Year - Trace # - Initials)
2. Date of Injection: 1 / 17 / 96 (Month / Day / Year) Time: ____ ( ) a.m. ( ) p.m.
3. Owner of Injection Site: Wright Phone: ( ) ____
4. Quadrangle/County: Allensville / Todd
5. Elevation: 535' (✓) map ( ) measured 6. Latitude: ____ Longitude: ____
7. Description of Injection Site:
   - ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   - ( ) losing stream (✓) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks ____
8. Formation Receiving Tracer Injection: Ste. Genevieve Limestone
9. Flow Conditions: ( ) low (✓) moderate ( ) high
10. Induced Flow? (✓) no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)
11. Tracing Agent: Amt 0.2 gal. ( ) Fluor. (✓) Rhod. WT ( ) OB ( ) DY96 ( ) other ____

## RECORD OF DYE TRACE

Principal Investigator Joseph A. Ray Field Personnel Bill Stapleton

Precipitation before & during trace ____

| ID | Location of Dye Receptors | Background | Results | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | 1-17 | 1-22 | 1-29 | 2-6 | | | | | | | | | | | |
| | Duration | | 5d | 12 | | | | | | | | | | | | |
| 25 | Duck Sp. | – | – | – | / | | | | | | | | | | | |
| 26 | Gorby Sp. | – | – | – | / | | | | | | | | | | | |
| 29 | Robertson Win. | – | – | – | / | | go to 96-2 (rep.) - JAR | | | | | | | | | |
| 32 | Barton Sp. | N | – | / | / | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

Legend:
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

Remarks ____

Interpretation ____

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. Name of Dye Trace (Site Location): Wright Swallet # 96-2(rep) JAR
   Year – Trace # – Initials
2. Date of Injection: 2 / 14 / 96 (Month / Day / Year) Time: 1:50 ( ) a.m. (✓) p.m.
3. Owner of Injection Site: Wright Phone: ( )
4. Quadrangle/County: Allensville / Todd
5. Elevation: 535 (✓) map ( ) measured 6. Latitude: Longitude:
7. Description of Injection Site:
   - ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   - ( ) losing stream (✓) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks
8. Formation Receiving Tracer Injection: Ste. Genevieve Ls.
9. Flow Conditions: ( ) low (✓) moderate ( ) high
10. Induced Flow? (✓) no ( ) yes ______ / ______ (Pre-injection / Post-injection) ______ minutes (Elapsed Time)
11. Tracing Agent: Amt 1.5 lb ( ) Fluor. ( ) Rhod. WT ( ) OB (✓) DY96 ( ) other

## RECORD OF DYE TRACE

Principal Investigator Joseph A. Ray Field Personnel Bill Stapleton

Precipitation before & during trace

| | Date | 2-14 | 2-20 | 2-27 | 3-4 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | |
| ID | Location of Dye Receptors | Background | Results | | | | | | | | | | | | |
| 25 | Duck Sp | — | — | — | —R | | | | | | | | | | |
| 26 | Gorby Sp | — | — | — | —R | | | | | | | | | | |
| 29 | Robertson Win. | — | — | —R | | | | | | | | | | | |
| 35 | Underflow Sp (up) | — | + | / | | END TRACE | | | | | | | | | |
| 36 | Underflow Sp (down) | N | ++ | / | | | | | | | | | | | |
| 37 | Elk Fork @ Railroad | / | / | ? | R | | | | | | | | | | |
| 38 | Elk Fork @ Bridge | — | + | — | R | | | | | | | | | | |
| 39 | Gorby Sp #2 | N | — | — | —R | | | | | | | | | | |
| 42 | Cave Sp | N | L | — | —R | | | | | | | | | | |
| 43 | Elk Fork @ Gorby | N | / | ? | R | | | | | | | | | | |
| 44 | Rum Sp. Cr. | — | / | — | R | | | | | | | | | | |
| 45 | Emancipation Sp | — | — | — | R | | | | | | | | | | |
| 46 | Gate Sp | N | — | — | —R | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

Legend:
- + Positive
- ++ Very Positive
- +++ Extremely Positive
- — Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

Remarks

Interpretation

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Thomas Pools # 97-27-JAR
   Year – Trace # – Initials

2. **Date of Injection:** 12 / 4 / 97 (Month / Day / Year) **Time:** 11:00 (✓) a.m. ( ) p.m.

3. **Owner of Injection Site:** thomas Estates **Phone:** ( )

4. **Quadrangle/County:** Herndon / Christian

5. **Elevation:** 520' (✓) map ( ) measured **6. Latitude:** ____ **Longitude:** ____

7. **Description of Injection Site:**
   ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   (✓) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks Infiltration through gravel

8. **Formation Receiving Tracer Injection:** ____

9. **Flow Conditions:** (✓) low ( ) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)

11. **Tracing Agent:** Amt 9 OZ. (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ____

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** ____

**Precipitation before & during trace** ____

| | Date | 12-4 | 12-12 | 12-17 | 1-13 | 1-22 | 1-29 | 2-6 | 2-20 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| **ID** | **Location of Dye Receptors** | **Background** | **Results** | | | | | | | | | | | | | |
| 1 | King Sp up | – | +++ | ++ | ++ | + | / | + | + | | | | | | | |
| 2 | King Sp Middle | N | +++ | / | + R | | | | | | | | | | | |
| 3 | King Sp Down | – | ++ | ++ | + | + | / | + | B+ | | | | | | | |
| 4 | King Sp Middle overflow | N | + | / | + R | | | | | | | | | | | |
| 5 | King Sp Bluehole | N | + | / | / | / | / | / | / | | | | | | | |
| 6 | McCraw Sp | N | – | – | – | – | P? | – | – | | | | | | | |
| 7 | Buchanan Sp | N | / | / | / | / | / | / | / | | | | | | | |
| 8 | Little River up from King Sp | | N | B+ | B+ R | | | | | | | | | | | |
| | | | | | From Hopkinsville STP | | | | | | | | | | | |
| 9 | Jones Mill Sp | | | | | N | – | – | – | | | | | | | |
| 1 | Walton Sp (changed to 11) | | | | N | – | – | – | go to 98-5-JAR | | | | | | | |
| 12 | Head of Casey Cr (12) | | | | N | – | – | – | | | | | | | | |
| 12 | Casey Cr above Head (13) | | | | N | – | – | – | | | | | | | | |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed
- P Poor Circulation

**Remarks** ____

**Interpretation** ____

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Smithson Insurgence # 98 - 2 - JAR (Rep) 4.20
Year – Trace # – Initials

2. **Date of Injection:** 1 (Rep) 4 / 13 9 / 98 98 **Time:** 4:22 ( ) a.m. (✓) p.m.
Month Day Year

3. **Owner of Injection Site:** Douglas Smithson **Phone:** (502) 271-2528

4. **Quadrangle/County:** Herndon / Christian

5. **Elevation:** 535' (✓) map ( ) measured 6. **Latitude:** ______ **Longitude:** ______

7. **Description of Injection Site:**
(✓) sinking stream ( ) sinkhole ( ) water well ( ) injection well
( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
( ) lagoon ( ) cave stream ( ) other

Remarks ______

8. **Formation Receiving Tracer Injection:** ______

9. **Flow Conditions:** ( ) low (✓) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ______ / ______ Pre-injection Post-injection ______ Elapsed Time minutes

11. **Tracing Agent:** Amt 0.5 - 0.75 lb (Rep) 1.0 oz ( ) Fluor. ( ) Rhod. WT ( ) OB (✓) DY96 ( ) other Fluor

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** ______
**Precipitation before & during trace** ______

| ID | Location of Dye Receptors | Background (Date 1-14) | 1-22 | 4-9 | 5-15 | | Results |
|---|---|---|---|---|---|---|---|
| 1 | King Sp, Down Up | | ? | – | + | R | |
| 3 | King Sp: Down | – | + | – | + | R | |
| 6 | McCraw Sp | | – | | | | |
| 9 | Jones Mill Sp | | N | | | | |
| 11 | Walton Sp | | – | | | | |
| 12 | Head of Casey Cr | | – | | | | |
| 13 | Casey Cr above #9 | | – | | | | |

**Legend:**
\+ Positive
\++ Very Positive
\+++ Extremely Positive
– Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed

**Remarks** ______
**Interpretation** Perennial distributary

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Roaring Spring Sink # 98 - 4 - JAR
   Year – Trace # – Initials
2. **Date of Injection:** 1 / 29 / 98 (Month / Day / Year) **Time:** 12:00 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** Jeff Choate **Phone:** (502) 271 - 2150
4. **Quadrangle/County:** Roaring Spring / Trigg
5. **Elevation:** 483 (✓) map ( ) measured 6. **Latitude:** ____________ **Longitude:** ____________
7. **Description of Injection Site:**
   ( ) sinking stream (✓) sinkhole ( ) water well ( ) injection well
   ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other
   Remarks: dye injected into trickle
8. **Formation Receiving Tracer Injection:** ____________
9. **Flow Conditions:** (✓) low ( ) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ________ / ________ (Pre-Injection / Post-Injection) ________ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 1.5 gal ( ) Fluor. ( ) Rhod. WT (✓) OB ( ) DY96 ( ) other ____________

## RECORD OF DYE TRACE

**Principal Investigator** ____________ **Field Personnel** ____________

**Precipitation before & during trace** ____________

| | Date | 1-29 | 2-6 | 2-20 | 3-4 | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Duration | | | | | | | | | | | | | | | |
| ID | Location of Dye Receptors | Background | Results | | | | | | | | | | | | | |
| 1 | King Sp Up | / | – | – | – | | | | | | | | | | | |
| 3 | King Sp Down | / | – | – | – | | | | | | | | | | | |
| 6 | McCraw Sp | – | – | – | – | | | | | | | | | | | |
| 9 | Jones Mill Sp | – | – | – | – | | | | | | | | | | | |
| 10 | Big Sulphur Cave Sp | N | – | – | – | | | | | | | | | | | |
| 11 | Walton Sp | – | ++ | + | – | | | | | | | | | | | |
| 12 | Head of Casey Cr | – | – | – | – | | | | | | | | | | | |
| 13 | Casey Cr above Head | – | – | – | – | | | | | | | | | | | |
| 14 | Jones Window | | N | + | R | | | | | | | | | | | |
| 15 | Moore Window | | N | + | R | | | | | | | | | | | |

**Legend:**
+ Positive
++ Very Positive
+++ Extremely Positive
– Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed

**Remarks** ____________

**Interpretation** ____________

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Garnett ~~Losing~~ Sinking Cr. # 98 - 5 - JAR
(Year – Trace # – Initials)

2. **Date of Injection:** 1 / 29 / 98 (Month / Day / Year) **Time:** 2:00 ( ) a.m. (✓) p.m.

3. **Owner of Injection Site:** William Garnett (or Phillips) **Phone:** (502) 886-6821 (shop)

4. **Quadrangle/County:** ____ / ____

5. **Elevation:** ____ ( ) map ( ) measured 6. **Latitude:** ____ **Longitude:** ____

7. **Description of Injection Site:**
( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
(✓) losing stream ( ) karst window ( ) monitoring well ( ) septic system
( ) lagoon ( ) cave stream ( ) other

Remarks ____

8. **Formation Receiving Tracer Injection:** ____

9. **Flow Conditions:** (✓) low ( ) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)

11. **Tracing Agent: Amt** 0.75 lb (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ____

## RECORD OF DYE TRACE

**Principal Investigator** ____ **Field Personnel** ____

**Precipitation before & during trace** ____

| [redacted] | | Date | | 1-29 | 2-6 | 2-20 | 3-4 |
|---|---|---|---|---|---|---|---|
| | | Duration | | | | | |
| **ID** | **Location of Dye Receptors** | | **Background** | **Results** | | | |
| 1 | King Sp Up | | | / | B* | B | — |
| 3 | King Sp Down | | | / | B | B | — |
| 6 | McCraw Sp | | | P? | — | — | |
| 9 | Jones Mill Sp | | | — | — | — | — |
| 10 | Big Sulphur Cave Sp | | | N | — | — | — |
| 11 | Walton Sp | | | — | — | +++ | + |
| 12 | Head of Casey Cr | | | — | — | — | — |
| 13 | Casey Cr above Head | | | — | — | — | — |
| 14 | Jones Window | | | | N | +++ | R |
| 15 | Moore Window | | | | N | +++ | R |

**Legend:**
+ Positive
++ Very Positive
+++ Extremely Positive
— Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed
P Poor Circulation

**Remarks** B* from test #97-27-JAR

**Interpretation** ____

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Walker Swallet # 98 - 8 - JAR
   Year – Trace # – Initials
2. **Date of Injection:** 3 / 17 / 98 (Month / Day / Year) **Time:** 2:30 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** Doug Walker **Phone:** (502) 886-2742
4. **Quadrangle/County:** Caledonia / Christian
5. **Elevation:** 495' (✓) map ( ) measured 6. **Latitude:** ______ **Longitude:** ______
7. **Description of Injection Site:**
   (✓) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks ______
8. **Formation Receiving Tracer Injection:** ______
9. **Flow Conditions:** (✓) low ( ) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ______ / ______ (Pre-injection / Post-injection) ______ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 3/8 gal ( ) Fluor. (✓) Rhod. WT ( ) OB ( ) DY96 ( ) other ______

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** ______
**Precipitation before & during trace** ______

| ID | Location of Dye Receptors | Back-ground | Results | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | 3-17 | 3-26 | 4-9 | 4-15 | 4-23 | 4-29 | 6-2 | | | | | | | | |
| | Duration | | | | | | | 6-3 | | | | | | | | |
| 1 | River Bend Sp | – | ++ | + | + | – | ? | – | | | | | | | | |
| 2 | Caledonia BH | – | – | – | – | – | – | – | | | | | | | | |
| 3 | Cane Overflow | – | – | – | – | – | / | – | | | | | | | | |
| 4 | Little River up from RiverBend Sp | N | – | – | – | –R | | | | | | | | | | |
| 5 | Sinking Fork up from #3 | N | P | –R | | | | | | | | | | | | |
| 6 | Baker Sp | N | – | / | – | / | / | / | | | | | | | | |
| 7 | Cane Sp | N | – | – | / | / | / | / | | | | | | | | |
| 8 | Brellsford Sp | N | – | – | – | – | – | / | | | | | | | | |
| 9 | Lawrence Boil | N | – | – | – | / | – | – | | | | | | | | |
| 10 | Mill Stream Sp | N | – | – | / | – | / | – | | | | | | | | |
| 11 | Stream @ Julien | N | – | / | –R | | | | | | | | | | | |
| 12 | Hardy Sp | N | – | / | / | / | / | / | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

**Legend:**
+ Positive
++ Very Positive
+++ Extremely Positive
– Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed
P Poor Circulation

**Remarks** ______

**Interpretation** ______

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

### TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Bradey Lane Swallet # 98 - 9 - JAR (Year - Trace # - Initials)
2. **Date of Injection:** 3 / 17 / 98 (Month / Day / Year) **Time:** 3:30 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** Billy Williams **Phone:** (502) 886-4566
4. **Quadrangle/County:** Church Hill / Christian
5. **Elevation:** 485' (✓) map ( ) measured 6. **Latitude:** ____ **Longitude:** ____
7. **Description of Injection Site:**
   - (✓) sinking stream ( ) losing stream ( ) lagoon
   - ( ) sinkhole ( ) karst window ( ) cave stream
   - ( ) water well ( ) monitoring well ( ) other
   - ( ) injection well ( ) septic system

   Remarks ____
8. **Formation Receiving Tracer Injection:** ____
9. **Flow Conditions:** (✓) low ( ) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 12 oz (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ____

### RECORD OF DYE TRACE

**Principal Investigator** Joseph Ray **Field Personnel** Phil O'dell

**Precipitation before & during trace** ____

| ID | Location of Dye Receptors | Date: 3-17 (Background) | 3-26 | 4-9 | 4-15 | 4-23 | 4-29 | 6-2 (Duration: 6-3) |
|---|---|---|---|---|---|---|---|---|
| 1 | River Bend Sp | — | — | — | — | — | — | — |
| 2 | Caledonia BH | — | — | — | — | — | — | — |
| 3 | Cane Overflow | — | — | — | — | — | / | — |
| 4 | Little River up from RiverBend Sp | N | — | — | B | BR | | |
| 5 | Sinking Fork up from #3 | N | P | —R | | | | |
| 6 | Baker Sp | N | — | / | — | / | / | / |
| 7 | Cane Sp | N | + | — | / | / | / | / |
| 8 | Brellsford Sp | N | — | — | — | — | — | — |
| 9 | Lawrence Boil | N | — | — | — | / | — | — |
| 10 | Mill Stream Sp | N | +++ | + | / | + | / | ? |
| 11 | Stream @ Julien | N | — | / | —R | | | |
| 12 | Hardy Sp | N | — | / | / | / | / | / |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- — Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed
- P - Poor Circulation

**Remarks** ____

**Interpretation** ____

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Sholar Swallet **#** 98 - 20 - JAR
   (Year – Trace # – Initials)

2. **Date of Injection:** 4 (Month) / 8 (Day) / 98 (Year) **Time:** 2:30 ( ) a.m. (✓) p.m.

3. **Owner of Injection Site:** ______ **Phone:** ( ) ______

4. **Quadrangle/County:** ______ / ______

5. **Elevation:** ______ ( ) map ( ) measured **6. Latitude:** ______ **Longitude:** ______

7. **Description of Injection Site:**
   - (✓) sinking stream
   - ( ) losing stream
   - ( ) lagoon
   - ( ) sinkhole
   - ( ) karst window
   - ( ) cave stream
   - ( ) water well
   - ( ) monitoring well
   - ( ) other
   - ( ) injection well
   - ( ) septic system

   Remarks ______

8. **Formation Receiving Tracer Injection:** ______

9. **Flow Conditions:** (✓) low ( ) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ______ (Pre-injection) / ______ (Post-injection) ______ (Elapsed Time) minutes

11. **Tracing Agent: Amt** 1 pint ( ) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 (✓) other Eocene

## RECORD OF DYE TRACE

**Principal Investigator** ______ **Field Personnel** ______

**Precipitation before & during trace** ______

| | **Date** | 4-9 | 4-15 | 4-23 | 4-29 | 5-15 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Duration** | | | | | | | | | | | | | | |
| **ID** | **Location of Dye Receptors** | **Back-ground** | **Results** | | | | | | | | | | | | |
| 8 | Brellsford Sp | – | – | – | – | – | | | | | | | | | |
| 9 | Lawrence Boils | – | – | / | – | / | end | | | | | | | | |
| 15 | Garnett Sp | – | +++ | / | + | ? | | | | | | | | | |
| 17 | Head of Casey Cr | | | | N | – | | | | | | | | | |
| | | | | | | | | | | | | | | | |
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**Legend:**
- + Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** ______

**Interpretation** ______

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Adams Swallet **#** 98-21-JAR
   Year – Trace # – Initials
2. **Date of Injection:** 4 / 8 / 98 (Month / Day / Year) **Time:** 4:40 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** ______ **Phone:** ( ) ______
4. **Quadrangle/County:** ______ / ______
5. **Elevation:** ______ ( ) map ( ) measured 6. **Latitude:** ______ **Longitude:** ______
7. **Description of Injection Site:**
   ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks ______
8. **Formation Receiving Tracer Injection:** ______
9. **Flow Conditions:** ( ) low ( ) moderate ( ) high
10. **Induced Flow?** ( ) no ( ) yes ______ / ______ (Pre-injection / Post-injection) ______ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 2 oz (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ______

## RECORD OF DYE TRACE

**Principal Investigator** ______ **Field Personnel** ______
**Precipitation before & during trace** ______

| ID | Location of Dye Receptors | Background | 4-9 | 4-15 | 4-23 | 4-29 | 5-15 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | | |
| 8 | Brellsford Sp | – | – | – | – | – | | | | | | | | | | | |
| 9 | Lawrence Boils | – | – | / | – | / | | | | | | | | | | | |
| 15 | Garnett Sp | – | – | / | – | – | | | | | | | | | | | |

(Results)

**Legend:**
+ Positive
++ Very Positive
+++ Extremely Positive
– Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed

**Remarks** Losing reach of eastern Trib. of Bunge Creek, 2.6 Mi SW of Brelsford Sp.
**Interpretation** Not Recovered – too little dye?

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Payneville Calvert # 98 - 25 - JAR
   Year – Trace # – Initials

2. **Date of Injection:** 4 / 22 / 98 (Month / Day / Year) **Time:** 3:40 ( ) a.m. (✓) p.m.

3. **Owner of Injection Site:** KY DOT **Phone:** ( )

4. **Quadrangle/County:** Irvington / Meade

5. **Elevation:** 790 (✓) map ( ) measured **6. Latitude:** **Longitude:**

7. **Description of Injection Site:**
   - ( ) sinking stream
   - (✓) losing stream
   - ( ) lagoon
   - ( ) sinkhole
   - ( ) karst window
   - ( ) cave stream
   - ( ) water well
   - ( ) monitoring well
   - ( ) other
   - ( ) injection well
   - ( ) septic system

   Remarks

8. **Formation Receiving Tracer Injection:**

9. **Flow Conditions:** ( ) low (✓) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ______ / ______ (Pre-injection / Post-injection) ______ minutes (Elapsed Time)

11. **Tracing Agent:** Amt 1 pint ( ) Fluor. (✓) Rhod. WT ( ) OB ( ) DY96 ( ) other

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Jack Moody

**Precipitation before & during trace**

| | | Date | | 4-28 | 5-6 | 5-14 | 5-21 | 5-28 | 6-4 | 6-11 | 6-25 | 7-9 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Duration | | | | | | | | | | | | | | | |
| ID | Location of Dye Receptors | | Background | Results | | | | | | | | | | | | | |
| 1 | French Cr. Sp. West | | | – | – | | | | | | | | | | | | |
| 2 | French Cr. Sp. East | | | – | – | – | | / | – | – | – | – | | | | | |
| 3 | French Cr. Overflow | | | – | / | | | | | | | | | | | | |
| 4 | Sp @ Bridge | | | – | – | | | | | | | | | | | | |
| 5 | Payneville Elem. | | | – | – | / | – | / | – | – | / | | | | | | |
| 7 | Oolite Sp | | | – | – | – | / | / | / | / | / | | | | | | |
| 9 | Head of Wolf Cr | | | – | ? | ? | / | + | ? | – | – | – | | | | | |
| 10 | Head of Sp. Cr. | | | / | / | / | – | / | / | – | / | – | | | | | |
| ~~11~~ | ~~Hamilton Hill BH~~ | | | ~~/~~ | ~~/~~ | ~~/~~ | ~~/~~ | | | | | | | | | | |
| 12 | Boiling Sp. | | | / | / | – | / | / | / | / | / | | | | | | |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks**

**Interpretation**

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Mathews Swallet **#** 98 - 26 - JAR
   Year – Trace # – Initials

2. **Date of Injection:** 4 / 22 / 98 (Month / Day / Year) **Time:** 3:50 ( ) a.m. (✓) p.m.

3. **Owner of Injection Site:** Mathews **Phone:** ( )

4. **Quadrangle/County:** Irvington / Meade

5. **Elevation:** 610 ( ) map ( ) measured **6. Latitude:** ______ **Longitude:** ______

7. **Description of Injection Site:**
   - (✓) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   - ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks ______

8. **Formation Receiving Tracer Injection:** ______

9. **Flow Conditions:** ( ) low (✓) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ______ / ______ (Pre-injection / Post-injection) ______ minutes (Elapsed Time)

11. **Tracing Agent:** Amt 10 oz. (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ______

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Jack Moody

**Precipitation before & during trace** ______

| ID | Location of Dye Receptors | Back-ground | 4-28 | 5-6 | 5-14 | 5-21 | 5-28 | 6-4 | 6-11 | 6-25 | 7-9 | 7-16 | 7-23 | 7-28 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| 1 | French Cr. Sp. West | | – | – | | | | | | | | | | | | |
| 2 | French Cr. Sp East | | – | – | – | | / | –B | – | –B | –B | –B | – | / | | |
| 3 | French Cr. Overflow | | – | / | | | | | | | | | | | | |
| 4 | Sp @ Bridge | | – | – | | | | | | | | | | | | |
| 5 | Payneville Elem. | | – | – | / | – | / | – | – | / | / | / | / | / | | |
| 7 | Oolite Sp | | B | – | – | / | / | / | / | / | / | / | / | / | | |
| 9 | Head of Wolf Cr. | | – | + | + | / | + | + | + | +? | –B | –B | – | – | | |
| 10 | Head of Sp. Cr. | | / | / | / | – | / | / | – | / | – | / | / | – | | |
| ~~11~~ | ~~Hamilton Hill BH~~ | | ~~/~~ | / | | | | | | | | | | | | |
| 12 | Boiling Sp. | | / | / | B | / | / | / | / | / | / | / | / | / | | |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** 1 through 4 consolidated at culvert

**Interpretation** ______

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Skinner Creek Swallet **#** 98 - 32 - JAR
   Year – Trace # – Initials
2. **Date of Injection:** 5 / ~~19~~ 15 / 98 (Month / Day / Year) **Time:** ________ ( ) a.m. ( ) p.m.
3. **Owner of Injection Site:** ________________ **Phone:** ( ) ________
4. **Quadrangle/County:** ________________ / ________________
5. **Elevation:** ________ ( ) map ( ) measured **6. Latitude:** ________ **Longitude:** ________
7. **Description of Injection Site:**
   - ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   - (✓) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks ________________
8. **Formation Receiving Tracer Injection:** ________________
9. **Flow Conditions:** ( ) low ( ) moderate ( ) high
10. **Induced Flow?** ( ) no ( ) yes ________ / ________ (Pre-injection / Post-injection) ________ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 6 oz (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ________

## RECORD OF DYE TRACE

**Principal Investigator** ________________ **Field Personnel** ________________

**Precipitation before & during trace** ________________

| | Date | 5-15 | 5-19 | 6-2 | 6-9 | 7-1 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| **ID** | **Location of Dye Receptors** | **Back-ground** | **Results** | | | | | | | | | | | | | |
| 8 | Brellsford Sp | — | — | — | / | — | | | | | | | | | | |
| 9 | Lawrence Bois | / | / | — | / | — | | | | | | | | | | |
| 15 | Garnett Sp. Main | — | — | — | — | — | | | | | | | | | | |
| 17 | Head of Casey Cr | — | ++ | ++ | / | + | | | | | | | | | | |
| 18 | Garnett Sp. South | N | — | — | / | — | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 13 | Casey Cr. above Head | N | / | / | / | — | | | | | | | | | | |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- — Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** ________________

**Interpretation** ________________

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

**TRACER INJECTION SITE**

1. **Name of Dye Trace (Site Location):** Brame Window # 98 - 22 - JAR (Rep)
   Year – Trace # – Initials
2. **Date of Injection:** 4 / 9 / 98 **Time:** 3:00 ( ) a.m. (✓) p.m.
   Month 6 Day 3 Year 98 1:25 ✓
3. **Owner of Injection Site:** David Brame **Phone:** ( )
4. **Quadrangle/County:** Church Hill / Christian
5. **Elevation:** 510' (✓) map ( ) measured **6. Latitude:** ____ **Longitude:** ____
7. **Description of Injection Site:**
   ( ) sinking stream ( ) ~~sinkhole~~ ( ) water well ( ) injection well
   ( ) losing stream (✓) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks ____
8. **Formation Receiving Tracer Injection:** ____
9. **Flow Conditions:** ( ) low (✓) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ____ / ____ ____ minutes
    Pre-injection Post-injection Elapsed Time
11. **Tracing Agent:** Amt 1/3 gal (Rep) 1/2 H2O3 (✓) Fluor ( ) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 (✓) other Eocene

**RECORD OF DYE TRACE**

**Principal Investigator** Joseph A. Ray **Field Personnel** Phil O'dell

**Precipitation before & during trace** ____

| ID | Location of Dye Receptors | Background | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | 4-9 | 4-15 | 4-23 | 4-29 | | | | | | 5-19 | 6-3 | 6-9 | 7-14 | | |
| | Duration | | | | | | | | | | | | | | | |
| | | | **Results** | | | | | | | | | | | | | |
| 1 | River Bend Sp | — | — | — | — | | | | | | | — | | | | |
| 2 | Caledonia BH | — | — | — | — | | | | | | | — | — | | | |
| 3 | Cane Overflow | — | — | — | / | | | | | | | — | | | | |
| 4 | Little River up from RiverBend Sp | — | — | —R. | | | | | | | | | | | | |
| 5 | Sinking Fork up from #3 | —R | | | | | | | | | | | | | | |
| 6 | Baker Sp | / | — | / | / | | | | | | | / | | | | |
| 7 | Cane Sp | — | / | / | / | | | | | | | / | | | | |
| 8 | Brellsford Sp | — | — | — | — | | | | | | | — | | | | |
| 9 | Lawrence Boil | — | — | / | — | | | | | | | — | | | | |
| 10 | Mill Stream Sp | — | / | — | / | | | | | | | — | | | | |
| 11 | Stream @ Julien | / | —R | | | 19 Adams Sp | | | | | — | — | ++ | ? | | |
| 12 | Hardy Sp | / | / | / | / | 20 Adams Sp Channel | | | | | | N | / | +++ | R | |
| 13 | Zook Sp | — | / | — | / | 21 Adams Bank | | | | | | N | / | +++ | R | |
| 14 | Smith Sp | — | / | — | / | 22 New House Sp | | | | | | N | / | +++ | R | |
| 16 | Lilly Sp | N | / | —R | | | | | | | | | | | | |

**Legend:**
+ Positive
++ Very Positive
+++ Extremely Positive
— Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed

**Remarks** Eocene detected at I-24 in Little River – Pete Idstion

**Interpretation** ____

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Kyler Tile Sink  **#** 98 - 36 - JAR
   (Year -- Trace # -- Initials)

2. **Date of Injection:** 6 / 2 / 98 (Month / Day / Year)  **Time:** 6:45 ( ) a.m. (✓) p.m.

3. **Owner of Injection Site:** ______  **Phone:** ( ) ______

4. **Quadrangle/County:** Cadiz / Trigg

5. **Elevation:** 485 (✓) map ( ) measured  **6. Latitude:** ______ **Longitude:** ______

7. **Description of Injection Site:**
   - ( ) sinking stream ( ) sinkhole ( ) water well (✓) injection well
   - ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks: 2 ft diameter concrete tile installed in sink which floods 15' deep

8. **Formation Receiving Tracer Injection:** ______

9. **Flow Conditions:** ( ) low (✓) moderate ( ) high

10. **Induced Flow?** ( ) no (✓) yes  20 gal (Pre-injection) / 180 gal (Post-injection)  15 (Elapsed Time) minutes

11. **Tracing Agent:** Amt 0.25 gal ( ) Fluor. (✓) Rhod. WT ( ) OB ( ) DY96 ( ) other ______

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray  **Field Personnel** Phil O'dell

**Precipitation before & during trace** ______

| ID | Location of Dye Receptors | Background (Date 6-2) | Results (Date 6-9) | Results (Date 6/17) | Results (Date 7-1) |
|---|---|---|---|---|---|
| 8 | Brellsford Sp | — | / | + | — |
| 9 | Lawrence Boils | — | / | / | +R |
| 15 | Garnett Sp Main | — | — | / | — |
| 17 | Head Casey Cr. | — | / | / | — |
| 18 | Garnett Sp South | / | / | / | — |
| 13 | Casey Creek above Head | / | / | / | — |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- — Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** ______

**Interpretation** ______

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Franks Blueho le #98 - 38 - JAR
   (Year – Trace # – Initials)
2. **Date of Injection:** 7 / 1 / 98 (Month / Day / Year) **Time:** 3:45 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** Allen Franks **Phone:** ( )
4. **Quadrangle/County:** Guthrie / Todd
5. **Elevation:** 575 (✓) map ( ) measured 6. **Latitude:** **Longitude:**
7. **Description of Injection Site:**
   ( ) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   ( ) losing stream (✓) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks
8. **Formation Receiving Tracer Injection:**
9. **Flow Conditions:** ( ) low (✓) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 1 oz (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Phil O'dell
**Precipitation before & during trace**

| ID | Location of Dye Receptors | Back-ground | 7-1 | 7-9 | 7-29 | 8-5 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| | | | Results | | | | | | | | | | | | | |
| 1 | Coblentz Sp #1 | N | + | R | | | | | | | | | | | | |
| 2 | Coblentz Sp #2 | N | + | R | | | | | | | | | | | | |
| 3 | Cain Window | N | + | R | | | | | | | | | | | | |
| 4 | Stooksbury Window | N | + | R | | | | | | | | | | | | |
| 5 | Barton Spring | – | – | – R | | | | | | | | | | | | |
| 9 | Oval Sp | / | / | / | – R | | | | | | | | | | | |

**Legend:**
+ Positive; ++ Very Positive; +++ Extremely Positive; – Negative Results
B Perceptible Background (slight); B+ Significant Background (problematic); NR Not Recovered (high water, stolen receptor, etc); R Receptor removed
/ Receptor Not Changed; L Receptor lost; N New Receptor Installed

**Remarks**

**Interpretation**

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Sinking Fork at Old Bridge **#** 98 - 41 - JAR (Year – Trace # – Initials)

2. **Date of Injection:** 7 / 22 / 98 (Month / Day / Year) **Time:** 10:00 (✓ a.m. ( ) p.m.

3. **Owner of Injection Site:** ____ **Phone:** ( ) ____

4. **Quadrangle/County:** Caledonia / Trigg

5. **Elevation:** 425' (✓ map ( ) measured **6. Latitude:** ____ **Longitude:** ____

7. **Description of Injection Site:**
   - (✓ sinking stream
   - ( ) losing stream
   - ( ) lagoon
   - ( ) sinkhole
   - ( ) karst window
   - ( ) cave stream
   - ( ) water well
   - ( ) monitoring well
   - ( ) other
   - ( ) injection well
   - ( ) septic system

   Remarks ____

8. **Formation Receiving Tracer Injection:** ____

9. **Flow Conditions:** ( ) low (✓ moderate ( ) high

10. **Induced Flow?** (✓ no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)

11. **Tracing Agent:** Amt 1/6 gal ( ) Fluor. (✓ Rhod. WT ( ) OB ( ) DY96 ( ) other ____

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Phil O'dell

**Precipitation before & during trace** ____

| ID | Location of Dye Receptors | Background (Date 7-22) | Results 7-28 | Results 8-12 | Results 8-19 |
|---|---|---|---|---|---|
| | Duration | | | | |
| 1 | Mill Stream Sp | – | ++ | / | – |
| 2 | Boatwright Hole | – | + | – | / |
| 3 | Pipeline Cave | – | – | – | / |
| 4 | McReynolds Win. | – | ++ | – | / |
| 5 | Roaring Crack | N | –R | | |
| 6 | Pool up from Roaring Crack | N | –R | | |
| 7 | Caledonia BH | L | – | / | – |
| 8 | Cane Sp (Cutoff sp) | | N | –R | |
| 9 | River Bend Sp | / | / | / | – |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** ____

**Interpretation** ____

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Swallet down from Roaring Crack **#** 98- 42 -JAR (Year – Trace # – Initials)
2. **Date of Injection:** 7 / 22 / 98 (Month / Day / Year) **Time:** 12:30 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** ______ **Phone:** ( ) ______
4. **Quadrangle/County:** Caledonia / Christian
5. **Elevation:** 428' (✓) map ( ) measured 6. **Latitude:** ______ **Longitude:** ______
7. **Description of Injection Site:**
   - (✓) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   - ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   - ( ) lagoon ( ) cave stream ( ) other

   Remarks ______
8. **Formation Receiving Tracer Injection:** ______
9. **Flow Conditions:** ( ) low (✓) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ______ / ______ (Pre-injection / Post-injection) ______ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 1/4 gal ( ) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 (✓) other Eocene

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Phil O'dell

**Precipitation before & during trace** ______

| ID | Location of Dye Receptors | Background (Date 7-22) | 7-28 | 8-12 | 8-19 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| 1 | Mill Stream Sp | – | + | / | – | | | | | | | | | | | |
| 2 | Boatwright Hole | – | ? | – | | | | | | | | | | | | |
| 3 | Pipeline Cave | – | – | – | | | | | | | | | | | | |
| 4 | McReynolds Win. | – | + | + | | | | | | | | | | | | |
| 5 | Roaring Crack | N | –R | | | | | | | | | | | | | |
| 6 | Pool up from Roaring Crack | N | –R | | | | | | | | | | | | | |
| 7 | Caledonia BH | L | – | / | – | | | | | | | | | | | |
| 8 | Cane Sp (Cut off sp) | | N | – | | | | | | | | | | | | |

**Legend:**
- + Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** ______

**Interpretation** ______

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

**TRACER INJECTION SITE**

1. **Name of Dye Trace (Site Location):** Bradey Lane Swallet # 98 - 9-JAR- Rep
Year – Trace # – Initials

2. **Date of Injection:** 7 / 22 / 98 (Month / Day / Year) **Time:** 1:00 ( ) a.m. (✓) p.m.

3. **Owner of Injection Site:** Billy Williams **Phone:** (502) 886-4566

4. **Quadrangle/County:** Church Hill / Christian

5. **Elevation:** 480' (✓) map ( ) measured 6. **Latitude:** ________ **Longitude:** ________

7. **Description of Injection Site:**
(✓) sinking stream ( ) sinkhole ( ) water well ( ) injection well
( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
( ) lagoon ( ) cave stream ( ) other

Remarks ________

8. **Formation Receiving Tracer Injection:** ________

9. **Flow Conditions:** ( ) low (✓) moderate ( ) high

10. **Induced Flow?** (✓) no ( ) yes ________ / ________ (Pre-injection / Post-injection) ________ minutes (Elapsed Time)

11. **Tracing Agent:** Amt 10 oz (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other ________

**RECORD OF DYE TRACE**

**Principal Investigator** Joseph A. Ray **Field Personnel** Phil O'dell

**Precipitation before & during trace** ________

| ID | Location of Dye Receptors | Back-ground (Date 7-22) | 7-28 | 8-12 | 8-19 |
|---|---|---|---|---|---|
| | Duration | | | | |
| 1 | Mill Stream Sp | B | +++ | / | + |
| 2 | Boatwright Hole | – | ++ | + | |
| 3 | Pipeline Cave | – | ++ | + | |
| 4 | McReynolds Win. | – | +++ | + | |
| 5 | Roaring Crack | N | +++ | R | |
| 6 | Pool up from Roaring Crack | N | ++ | R | |
| 7 | Caledonia BH | L | – | / | – |
| 8 | Cave Sp (cutoff) | | N | – | |

**Legend:**
+ Positive
++ Very Positive
+++ Extremely Positive
– Negative Results
B Perceptible Background (slight)
B+ Significant Background (problematic)
NR Not Recovered (high water, stolen receptor, etc)
R Receptor removed
/ Receptor Not Changed
L Receptor lost
N New Receptor Installed

**Remarks** ________

**Interpretation** ________

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** McCoy Sinkhole # 98 - 43 - JAR
   (Year -- Trace # -- Initials)
2. **Date of Injection:** 7 / 23 / 98 (Month / Day / Year) **Time:** 5:00 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** Mrs McCoy **Phone:** ( )
4. **Quadrangle/County:** GUSTON / MEADE
5. **Elevation:** 670' (X) map ( ) measured 6. **Latitude:** **Longitude:**
7. **Description of Injection Site:**
   ( ) sinking stream (✓) sinkhole ( ) water well ( ) injection well
   ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks
8. **Formation Receiving Tracer Injection:**
9. **Flow Conditions:** ( ) low (✓) moderate ( ) high
10. **Induced Flow?** ( ) no (✓) yes 50 gal (Pre-injection) / 350 gal (Post-injection) 180 (Elapsed Time) minutes
11. **Tracing Agent:** Amt 2 oz (✓) Fluor. ( ) Rhod. WT ( ) OB ( ) DY96 ( ) other

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Jack Moody + Pat Keefe

**Precipitation before & during trace**

| ID | Location of Dye Receptors | Background | 7-28 | 8-5 | 8-13 | 8-20 | 8-27 | 9-3 | 9-10 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Duration | | | | | | | | | | | | | | | |
| 1 | Ekron #1 | | – | – | – | – | – | – | – | | | | | | | |
| 2 | Ekron #2 | | – | – | – | – | – | – | – | | | | | | | |
| 3 | Ekron #3 | | – | – | – | – | – | – | – | | | | | | | |
| 11 | Hamilton Hill BH | | – | + | L | L | N | / | B | end trace ✓ | | | | | | |

**Legend:**
- + Positive
- ++ Very Positive
- +++ Extremely Positive
- – Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks**

**Interpretation**

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993

## TRACER INJECTION SITE

1. **Name of Dye Trace (Site Location):** Vessels Spring # 98 - 44 - JAR
   (Year – Trace # – Initials)
2. **Date of Injection:** 7 / 28 / 98 (Month / Day / Year) **Time:** 3:48 ( ) a.m. (✓) p.m.
3. **Owner of Injection Site:** Mrs. Vessels **Phone:** ( )
4. **Quadrangle/County:** IRVINGTON / MEADE
5. **Elevation:** 660' (✓) map ( ) measured **6. Latitude:** ____ **Longitude:** ____
7. **Description of Injection Site:**
   (✓) sinking stream ( ) sinkhole ( ) water well ( ) injection well
   ( ) losing stream ( ) karst window ( ) monitoring well ( ) septic system
   ( ) lagoon ( ) cave stream ( ) other

   Remarks ____
8. **Formation Receiving Tracer Injection:** ____
9. **Flow Conditions:** (✓) low ( ) moderate ( ) high
10. **Induced Flow?** (✓) no ( ) yes ____ / ____ (Pre-injection / Post-injection) ____ minutes (Elapsed Time)
11. **Tracing Agent:** Amt 4 gal ( ) Fluor. (✓) Rhod. WT ( ) OB ( ) DY96 ( ) other ____

## RECORD OF DYE TRACE

**Principal Investigator** Joseph A. Ray **Field Personnel** Jack Moody, Pat Keefe

**Precipitation before & during trace** ____

| ID | Location of Dye Receptors | Background (7-28) | 8-5 | 8-13 | 8-20 | 8-27 | 9-3 | 9-10 | 9-17 | 10-1 | 10-8 | | | 12-9 | 12-16 | 12-22 | 1-6 | 2-16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Duration | | | | | | | | | | | | | | | | | | |
| B5 | PAYNEVILLE ELEM | — | — | | — | — | — | — | — | — | — | | | — | — | — | — | / |
| B9 | HEAD OF WOLF | | — | — | — | — | — | / | / | — | — | | | ++ | + | + | + | — |
| B10 | HEAD OF SPRING | | — | / | — | / | — | / | / | / | — | | | / | — | / | / | / |
| B16 | LAPLAND SP | | — | — | / | — | / | / | / | — | / | | | | | | | |

**Legend:**
- \+ Positive
- ++ Very Positive
- +++ Extremely Positive
- — Negative Results
- B Perceptible Background (slight)
- B+ Significant Background (problematic)
- NR Not Recovered (high water, stolen receptor, etc)
- R Receptor removed
- / Receptor Not Changed
- L Receptor lost
- N New Receptor Installed

**Remarks** See 98-57 for possible recovery five months later

**Interpretation** — Recovery delayed by dry fall weather

*Please identify injection and recovery sites on photocopy of topographic map.* Kentucky Division of Water 10/1993